JAN 9 1922

Vol. IV, No. 3 PSYCHOLOGICAL REVIEW PUBLICATIONS JUNE, 1921

Journal of Experimental Psychology

EDITED BY

JOHN B. WATSON, 244 Madison Ave., New York City.
HOWARD C. WARREN, Princeton University (*Review*)
JAMES R. ANGELL, Yale University (*Monographs*)
SHEPHERD I. FRANZ, Govt. Hosp. for Insane (*Bulletin*) and
MADISON BENTLEY, University of Illinois (*Index*)

ADVISORY EDITORS

H. A. CARR, University of Chicago; RAYMOND DODGE, Wesleyan University; KNIGHT DUNLAP, Johns Hopkins University; H. S. LANGFELD, Harvard University; E. L. THORNDIKE, Columbia University.

CONTENTS

A Mirror Recorder for Photographing the Compensatory Movements of Closed Eyes: Raymond Dodge, 165.

A Method for Measuring Retinal Sensitivity: Percy W. Cobb and Mildred W. Cobb, 187.

Improvement in Brightness Discrimination and its Bearing on a Behavioristic Interpretation of Perception: Edward S. Jones, 198.

Physical Attractiveness and Repulsiveness: F. A. C. Perrin, 203.

Apparatus for the Study of Visual After Images: Donald A. Laird, 218.

The Relation between Intensity of Sensation by Attention: S. M. Newhall, 222.

An Experiment on Voice Reaction: Knight Dunlap, 244.

PUBLISHED BIMONTHLY BY

PSYCHOLOGICAL REVIEW COMPANY

LANCASTER, PA., QUEEN ST. AND PRINCETON, N. J.

Entered as second-class matter at the post-office at Lancaster, Pa., pending

Journal of
Experimental Psychology

VOL. IV, No. 3 JUNE, 1921

A MIRROR-RECORDER FOR PHOTOGRAPHING THE COMPENSATORY MOVEMENTS OF CLOSED EYES

BY RAYMOND DODGE

Wesleyan University

Any project that involves photographic records of reactive compensatory eye-movements, as in the ocular nystagmus of rotation, is embarrassed by a unique technical difficulty that has hitherto been prohibitive. In order to register eye-movements that are pure compensations, free from visual stimuli and visual controls, the records must be taken either in the dark or from closed eyes. Both conditions make photographic technique somewhat difficult. Photography in the dark seems quite impracticable. Photographing the position of the eye through closed eyelids for a long time seemed no less so.

Neither the dark nor closed eyelids are necessarily prohibitive. But for many years the technical difficulties prevented our completing the description of the five types of eye-movements in the horizontal meridian plane of the field of regard which was begun in 1903.[1] Discussing the reactive compensatory eye-movements in that paper, in contradistinction from the coördinate compensatory, I was obliged to say: "Unfortunately, the essential condition of the phenomenon in pure form is that the eyes be closed. This, however, precludes a quantitative investigation by any of the methods at hand." The first photographic records of the reactive compensatory eye-movements were taken by Holt.[2] He avoided the technical difficulties by frankly

[1] *Am. Jr. Physiology*, 1903, 8, 307–329.

[2] *Harvard Psychological Studies*, Vol. II., 1906, 57–66.

keeping the eyes open, and recorded the eye-movements by our method of the corneal reflection. The difficulty of revolving the long enlarging camera with the subject was avoided by confining his records to the post-rotation nystagmus ('after-nystagmus') which could be photographed by leaving the camera fixed and rotating the subject into position.

From time to time I planned various solutions of the technical difficulties. None of them materialized satisfactorily. Many years ago I tried to work out a pneumatic transmission system depending on the eccentric cornea. Recorders of this order have been used by Schackwitz,[1] Buys[2], and others. The published records show the same faults that deterred me from utilizing this method.[3]

Presumably the best method hitherto published is that of Struycken.[4] He is reported to have photographed a minute polished ball mounted on three feet and attached to the cornea by minute hooks. A total reflection prism in front of the lens permitted simultaneous records of both horizontal and vertical components. I know the method only second-hand.[5] But like the method of the corneal reflection it seems to depend on keeping the eye open. The use of the total reflection prism is a technical expedient of unlimited usefulness. Whether the mode of attaching the polished ball is an improvement over Judd's Chinese white spot[6] and my paraffined tissue paper mounting[7] can only be determined by experience. Personally I confess to some prejudice in favor of a technique that makes the least demands on the subject's ability to stand discomfort.

The possibility of photographing the movements of the eyes in visual darkness by means of the ultra-violet light did not escape us. In view of the possible deleterious effects of ultra-violet light, we hesitated to use it.

In 1916, with the help of my laboratory students we began

[1] *Zsch. f. Psychol.*, 1912, *63*, 442–453.
[2] *Internat. Zentralbl. f. Ohrenhk.*, 1910, *9*, 57–65.
[3] *Psychological Bulletin*, 1916, *13*, 422.
[4] *Ned. Tijdschr. v. Gen.*, 1918, *1*, 621.
[5] *Zeitsch. f. Psy.*, 1920, *85*, 345.
[6] *Yale Psychological Studies*, New Series, 1905, Vol. I., No. 1.
[7] *Monograph Supplement Psychol. Rev.*, 1907, No. 35.

to record photographically the eye-movements that were hidden under closed lids. This is the method that the present paper is to report.

Theory of the Mirror-Recorder for Closed Eyes

The principle of the recorder is that a surface which presses against the lid and is free to move will tend to assume a position tangential to the underlying corneal surface. That is to say, a mirror which reflects a recording beam of light, will be rotated from side to side as the apex of the cornea passes underneath.

Assuming for convenience an appropriate source of illumination and a suitable recording camera, the relation between eye-movement and records from a mirror resting on the eye-lid over the cornea will depend on the following considerations:

1. A mirror which is pressed lightly against the lid over the cornea will always tend to assume a position tangential to the surface of the cornea on which it rests as far as this is permitted by its mounting. For example, if the apex of the cornea moves clockwise underneath that part of the lid against which a mirror is resting, and if the mirror is free to rotate on an axis that is parallel to the axis of the eye's rotation, as the apex of the cornea passes underneath the mirror it will rotate the latter counter-clockwise. A recording beam of light from the mirror will consequently be rotated counter-clockwise when the eye rotates clockwise. With a fixed source of light its angular displacement will be double that of the mirror.

2. The angular displacement of the mirror will depend on the following factors: (*a*) The angular displacement of the eye. (*b*) The geometrical relationship between the radius of curvature of the cornea and that of the eyeball. The greater the differences in curvature the greater will be the movement of the mirror. (*c*) The relative position of the mirror with respect to the apex of the cornea. The greatest conceivable angular rotation of the mirror would result if the apex of a cornea of zero radius of curvature, infinitely

eccentric to the globe of the eye, just passed the axis of the recording mirror. On the contrary, no movement of mirror would result if it rested on a spherical eyeball while the latter rotated on its geometrical center. (*d*) The thickness and stiffness of the intervening lid. If the lid were totally unyielding all movement of the mirror would cease. If the lid conformed absolutely to the underlying surface it would operate on the geometrical relations as an increased radius of curvature of the cornea. (*e*) The intercurrent movements of the lid. Unless the lid is prevented from moving, voluntarily or by a lid-holder, all lid-movements will operate to move the mirror as though the eye moved.

For obvious reasons it is unnecessary to express these factors in the form of an equation. It would not be simple, and it would be worse than useless in practice if it gave the illusory security in uncontrolled results that mathematical elaboration sometimes produces. A relatively simple geometrical construction (Fig. 1) will indicate the primary relationship between the cornea and globe of the eye as it affects the movement of the recording mirror.

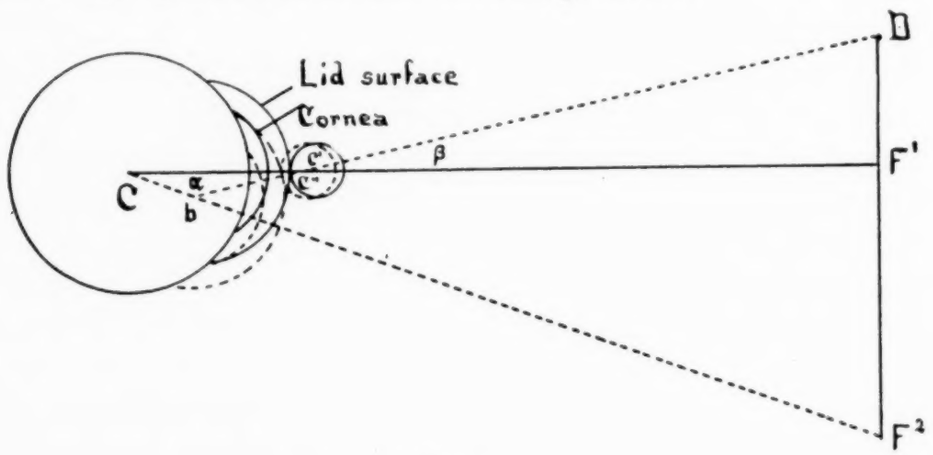


FIG. 1.

In Fig. 1 let CF^1 and the dotted line CF^2 represent successive positions of the line of regard, 20° apart. A recording mirror mounted with its axis on the line CF^1 at the point c^1, and resting on the closed lid over the apex of the cornea, will project a recording beam of light which originates at F^1 along the line of its incidence and back to the point of its

origin. When the line of regard moves clockwise to the position CF^2, the mirror will move to a new position tangential to the surface of the cornea which now underlies it, and the recording beam will be deflected counter-clockwise. In this new position of the mirror the line bD drawn from the center of curvature of the cornea at its second position through the axis of rotation of the mirror will be normal to the surface of the mirror. The consequent deflection of a recording beam of light originating at F^1 will be $c''F^1(\tan 2\beta)$. Since $\angle\beta$ is known from our knowledge of the triangle Cbc'', the ideal displacement of the recording light for any angle of eye-movement is directly calculable. Unfortunately, however, we have at present no way of controlling the position of the closed eye with sufficient accuracy to insure the optimum position of the mirror on a principal meridan of the cornea. Our theoretical construction is practically of little use as a basis for the quantitative evaluation of the records.

The thickness of the lid (condition *d*) operates to increase the effective diameter of the cornea about 1.5 mm. to 2 mm.

Movements of the eyelid (condition *e*) seriously complicate every record where they occur. The experimenter must learn to recognize the main forms of lid curves. The most common seems to be due to the lid-reflex and consists of a movement of the closed lid downward and nasalward. This always produces a sharp break in the eye curve in the same direction, with a slow recovery. It is quite unmistakable. Lid-movements which are coördinate with eye-movements and troublesome lid-tremors may be eliminated by a suitable eyelid holder pressing the lashes or a fold of the skin of the eyelid against the orbital edge of the superior maxillary bone. I have found no way to eliminate the reflex lid-movements. A lid-holder only reduces their amplitude.

It is obvious that our warning against trusting the geometrical constructs is quite justified. Each set-up must be empirically controlled, and the empirical data must be checked as often as necessary to prevent changes in the significant factors.

In my own case I have been interested principally with

the time relations of the various phases of the eye-movements. Quantitative spatial interpretations will force themselves on our attention in a later paper when we come to discuss the adequacy of the eye-compensations. In that connection we shall discuss the empirical controls. All forms of eye-movement recorders, even under the most favorable techniques with the eyes open, are less well adapted to record positions of the point of regard than they are the direction and duration of movements.[1] In this respect the mirror recorder is no exception. All spatial interpretation of eye-movement records must be undertaken with full understanding of the difficulties involved. They have as much credibility as their controls guarantee, no more.

With this proviso the mirror recorder furnishes a useful and economical instrument for a considerable number of experimental projects and class-room demonstrations. It will demonstrate the main characteristics of the eye-movements in reading, to an entire class. Wherever binocular reading is not demanded it will record the number, duration, and approximate positions of the reading pauses in experimental studies of reading. Its technical advantages over other forms of photographic recorders for these purposes are its ease of adjustment, freedom from abnormal lighting, economy of material and time, and low first cost.

Wherever conjugate movements of the eyes may be postulated, this recorder furnishes the simplest experimental technique for control of the eye-movements in experimental studies of any mental process where they may be supposed to interact. It is adequate for the study of the velocity of eye-movements, and the characteristics of pursuit movements. It is more especially indicated whenever it is desirable to observe or record the action of closed eyes.

Construction of the Mirror-Recorder

The principles of the mirror-recorder permit the widest possible variations in construction to meet experimental conditions. Wherever the head may be fixed we use a simple adjustable arm to hold the mirror against the lid.

[1] *Psychological Review Monograph Supplement*, No. 35, pp. 84 ff.

This would be represented by one of the mirror-arms of the complete instrument which we will describe in detail.

Our mirror-recorder was designed to meet the following requirements:

1. A rigid frame which can be attached to any shaped head and will not vibrate when the head moves. This must be so made that the adjustable attachments for the recording mirrors will interfere least with the supports for the head and other experimental attachments.

2. Attachments to this frame must hold the mirrors against the eyelids with a gentle and even pressure. They must be adjustable horizontally to interocular distance; vertically, to the horizontal meridian of the eye. Secondary adjustments must permit the direction of the recording beam to the slit of the recording camera.

3. The recording mirrors should project a sharply defined image of suitable shape and dimensions. They must be so mounted on the arms that hold them, that they are free to rotate in conformity to the position of the cornea. At least, they must rotate freely on an axis that is parallel to the axis of the eye-movements which they are to record.

Several successive models of the recorder were constructed to meet these requirements. Only the final form will be described. It is pictured in Fig. 2 and in Fig. 3.

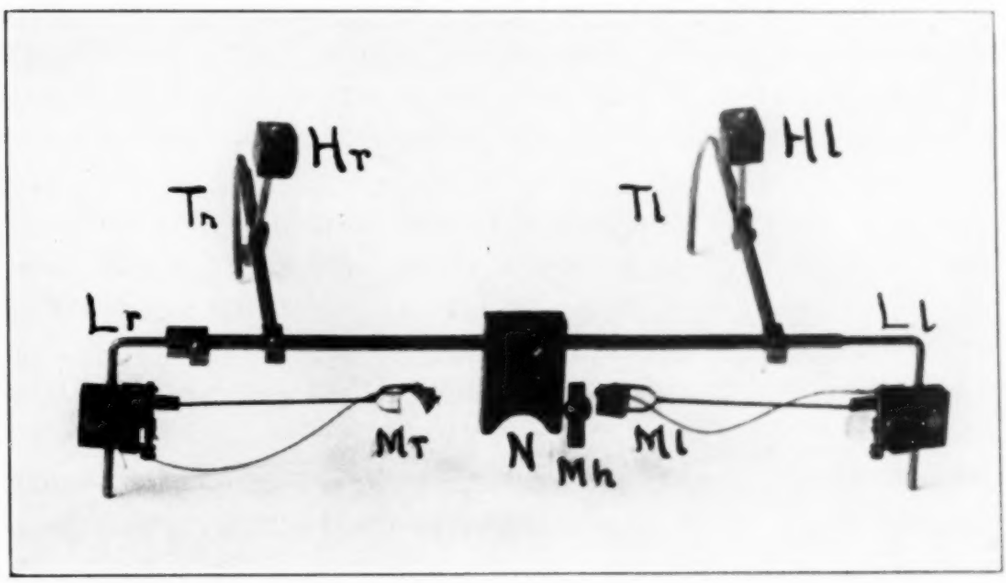


FIG. 2.

The frame resembles a spectacle frame with adjustable nose-piece, temples, and secondary side supports to the head. These five supports make the frame quite rigid and free from accidental vibration. The skeleton of the frame is constructed from $\frac{1}{8}$ in. brass tubing and resembles in form a capital letter *E*. The central offset from the stem would

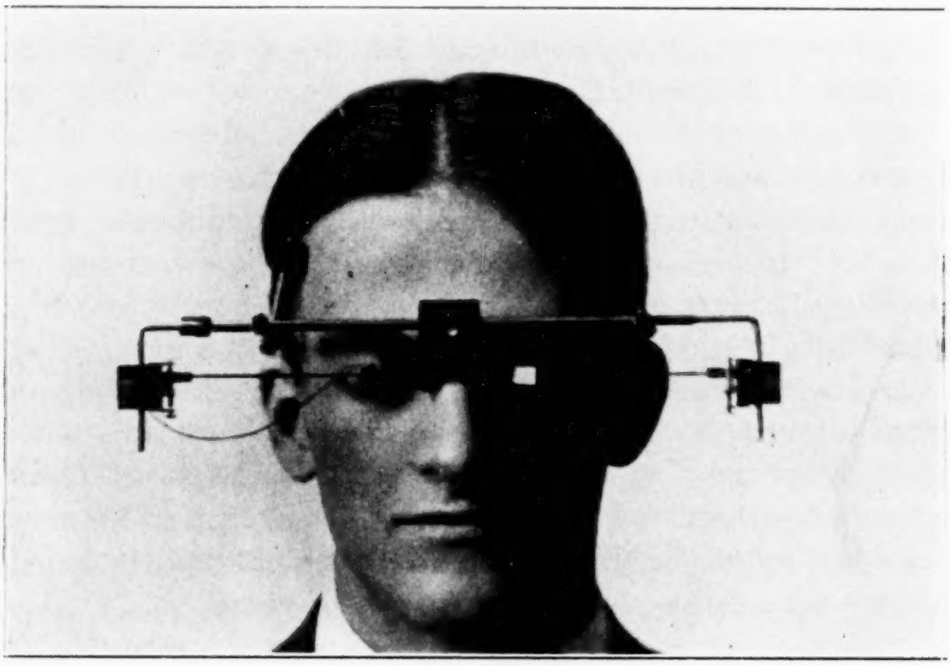


FIG. 3.

represent the nosepiece, Fig. 1, *N*. It is made of hard rubber, shaped to rest on the bridge of the nose, and may be clamped to the main stem at any angle to the temples. The longer offsets at the top and bottom of the *E* represent the temple tubes that hold the adjustable "riding" temple bars *Tr* and *Tl*. The temple tubes are made of $\frac{1}{8}$ in. tubing like the main stem. They may be adjusted to any position on the main stem corresponding to the width of the subject's head. The riding temple bars fit somewhat snugly into the temple tubes and are adjusted to fit over the ears of the subject when the frame is put on.

Into the ends of the main stem tube are thrust the longer arms of two L bars, *Lr* and *Ll*. On their shorter arms these L bars carry hard rubber blocks which may be clamped at

various heights and angles. To these are attached the small cone bearings that carry the light steel arms on which the recording mirrors are pivoted, *Mr* and *Ml*.

Starting with the recording mirrors we may recapitulate the supporting members as follows: Each recording mirror is held against the closed eyelid by a light forked, steel bar (see Fig. 3). The axis of this bar is on a hard rubber block which is clamped to the short arm of an L bar. The long arm of the latter slides in and out of the main tube stem to adjust the mirrors to the correct pupillary distance, and to the position of the resting eyes. When properly adjusted these bars hold the mirrors gently against the eyelids. They are free to move horizontally as the apex of the cornea passes underneath the mirrors. The mirror arms terminate in a fork which is drilled to receive a needle, the axis of the small block that holds the mirror.

In adjusting the frame to a subject we follow this general routine:

1. The temple tubes are loosened on the main stem and separated just enough to permit the riding temple bars to clear the subject's head.

2. The riding temple bars are adjusted behind the ears to hold the frame firmly in place without discomfort.

3. The vertical offsets from the temple tubes, *Hr* and *Hl*, are pressed gently but firmly against the head above the frame.

4. The subject is then brought into position on the experimental table, facing the recording camera. The head-line mirror *Mh* is adjusted until the image of the recording light falls across the exposure slit of the camera.

5. Then, one after the other, the mirror arms are adjusted to bring the eye-recording mirrors in contact with the lids at such positions and angles that each rests as accurately as possible over the apex of the cornea, while projecting the recording beam of light onto the exposure slit of the recording camera.

Fig. 3 shows the instrument in position for binocular records.

The recording camera for use with the mirror recorder should accommodate photographic film or paper as wide as five inches. We find the Dodge-Cline camera useful. It takes plateholders which are fitted with adapters for paper.

Our experimentation with sources of the recording light extended over several months. We find the most satisfactory source of the recording beam to be a commercial 100-watt nitrogen-filled incandescent lamp with a horseshoe-shaped filament. This we house to cut out irrelevant illumination, and place on the recording camera at a suitable height, with the plane of the filament in the sagittal plane of the subject's head. A plane mirror placed just above the slit at forty-five degrees to the vertical front of the camera reflects the recording beam to the concave mirrors of the mirror recorder. These in turn project a sharp image of the incandescent filament across the exposure slit of the recording camera. We find the horseshoe filament preferable to the arc light not only because it requires less attention and is steadier, but also because a recording line crossing the exposure slit is safer than a point of light from the arc-crater. Such a line does not leave the slit in slight movements of the head.

Any rapid photographic paper will give satisfactory records if the illumination is properly adjusted. We are best pleased with 'Insurance Bromide No. 2.' For slow records we interpose a filter between the lamp and the eyes. Paper will give excellent records up to 6 cm. per 1″. Beyond that speed, if the slit is kept fine, we get better results with plates.

A METHOD FOR MEASURING RETINAL SENSITIVITY[1]

BY CAPTAIN PERCY W. COBB, M.C. AND MILDRED W. LORING

Medical Research Laboratory, Air Service, U. S. Army, Mitchel Field, Garden City, L. I., N. Y.

Acknowledgment

The authors wish to acknowledge the courtesy of Nela Research Laboratories, for extending the facilities of the laboratory and permitting the expenditure of time, without which this paper could not well have been completed.

Introductory

In examining the candidate for flying status during the national emergency the search for a means of rating the visual capacity better and more complete than the usual letter test recalled the fact, already known to workers in sense-physiology, that attempts to measure visual sensitiveness to perception of small contrasts gave highly variable results, ambiguous unless time were taken to accumulate a large number of data, from which the effect of the variations could be eliminated by taking the average. The variations in such results are comparable, in their order of magnitude, to the very quantity which they measure, and the attempt to make such measurements, within the limits of time available and of equipment as yet adapted to the use of the ophthalmologist gave results which were unsatisfactory and meaningless.

A test at one time experimentally practiced in the Air Service involved the use of a smoke wedge.[2] The subject was to draw the wedge slowly across a sight-hole until the

[1] Published with permission of the Surgeon General, U. S. Army, who is not responsible for any opinion expressed or conclusions reached herein.

[2] (*a*) 'Manual of Medical Research Laboratory,' Washington, Government Printing Office, 1918, p. 140, and pp. 145, 146; also (*b*) Air Service Medical, same, same, 1919, p. 270, and pp. 275, 276. The text referred to in these two volumes is almost if not quite identical.

test object ceased to be distinguishable. This latter was a 1-inch square of gray, mounted centrally upon a 2-inch square of lighter gray paper 'where there are 13 perceptible differences between the two squares' (Nos. 32 and 19 respectively, in the series of papers in which white is No. 1, and black is No. 50). As a check, the same device was used, except that the smaller square was replaced by a 20/50 Snellen illiterate 'E' of the same gray. This was the procedure for contrast sensitivity. For threshold sensitivity, the test object used was a 3 millimeter aperture in the iris diaphragm on the De Zeng stand, with specifications as to the lamp used and as to the general conditions of illumination of the room as they would affect the state of adaptation. In all cases the test was to be accomplished in not less than 5, nor more than 8 seconds, in order that the progress of adaptation of the eye during the performance of the test might not be too variable a factor in the result. Average results are in print.[1] Also certain results as to light and color threshold obtained under diminished oxygen during the rebreather test, but these are only stated in percentages based on the total number of cases, in which rise, fall or no change were found; and we are left to guess at the actual number of cases examined, and hence also at the significance of the results stated. The use of the wedge has since been abandoned for reasons which have just been mentioned.

Various letter charts, in which lines of letters are of uniform size, and are in graded degrees of contrast with the background, have also been tried. Notable, among these, is a set included in the work of DeWecker and Masselon which one of us [2] once attempted to use. It soon appeared, however, that there were greater differences of visibility between the various letters of the same line than there were on the whole between the successive differently contrasting lines.

Nevertheless, since the ordinary Snellen chart, or other letter or character chart measures minimal size while presenting maximal contrast, it is eminently adapted to estimating

[1] *Loc. cit.*, (*a*) pp. 288, 289; (*b*) pp. 158, 159.

[2] Cobb, *Psychological Review*, XXVI., 1919, p. 447 ff.

such factors as determine the geometric accuracy of the image, namely, the dioptric conditions of the eye, and it is only in a very incidental way dependent upon the susceptibility of the retina itself to light or light-changes. It apparently does not report changes or differences in retinal sensitiveness within the limits of normal function, and in disease of the retina the impairment in visual acuity is generally enormous. In short, with the test-letters the retina is 'everything or nothing,' and it is this fact that leaves it to be desired that some method be devised which actually measures retinal sensitivity, both as to individual differences, and as to functional differences within the individual.

The selection of the method used in the work herein described arose from considerations developed in a previous communication, to which the reader is referred for a fuller discussion.[1] Briefly, the plan of using a stimulus of minimal area, and of minimal duration, has been adopted and followed as the result of the consideration that these experimental conditions closely represent the common and usual conditions of retinal stimulation occurring in the course of ordinary critical eye-work, and that these conditions are almost identical with those confronting the aviator or aerial navigator who is on the alert to detect an enemy air-craft at the longest possible range. Stated in another way, the method rests upon the use of a stimulus which is within such limits of magnitude, both spatial and temporal, that it may physiologically be considered as being a point and existing for an instant of time; the only implication of this delimitation being the condition that within these limits the product of time and area shall, other things equal, be constant for a given sensory effect. That such a condition may be realized within limits, will appear from what follows.

It is to be added, before proceeding with a description of the apparatus, that this method is perfectly applicable to the study of dark adaptation, with, of course, different limitations involving certain essential changes as to dimensions and as to

[1] Cobb, 'The Momentary Character of Ordinary Visual Stimuli,' *Psychobiology*, II., pp. 237 to 244.

general plan of construction, but without any change whatever as to the principle involved.

But since it is generally, if not universally, accepted that vision at comparatively high intensities of light, or 'day-vision' depends upon organs anatomically distinct from those involved in 'night' or 'twilight vision' and concerned in dark-adaptation, and since it is a fact that the two phases of vision so distinguished have quite different characteristics, it follows that the experimental findings derived from one of these conditions cannot be used as a basis of rating with respect to the other.

Apparatus and Methods

The apparatus used in this work consists of an illuminated screen, S, Fig. 2, 76×60 cm., with a small circular aperture at its center. The face of this screen is illuminated by two lamps, as shown in Fig. 1, at the same height as its center, 88 cm. distant from each other and in a horizontal line 50 cm. from the plane of the screen. Back of the central aperture and about 30 cm. distant, is a small screen, S', Fig. 2, illuminated independently by a third lamp, L_3. The three lamps are 6-to 8-volt headlight lamps, vacuum type tungsten filament, the first two rated at $2\frac{1}{2}$ amperes, the third at 2 amperes. The current was supplied by a motor-generator set rated on the generator side, for direct current, at 30 volts, 5 amperes, and at the low voltage used it carried the necessary current (about $6\frac{1}{2}$ amperes) well. The generator being shunt-wound, adjustment was effected by means of a rheostat which directly reduced the current in the field-magnets, and only secondarily by resistance thrown into the external circuit. Slight fluctuations in the current were prevented by floating a battery of seven Edison alkaline storage cells on the line. (Eight cells would have served better.)

When the brightness of the small back screen is just equal to that of the main screen, the observer, sitting directly before the aperture, is not able to distinguish the latter at all, not even at fairly close range. If an opaque object be now interposed behind the aperture, the latter becomes, in appear-

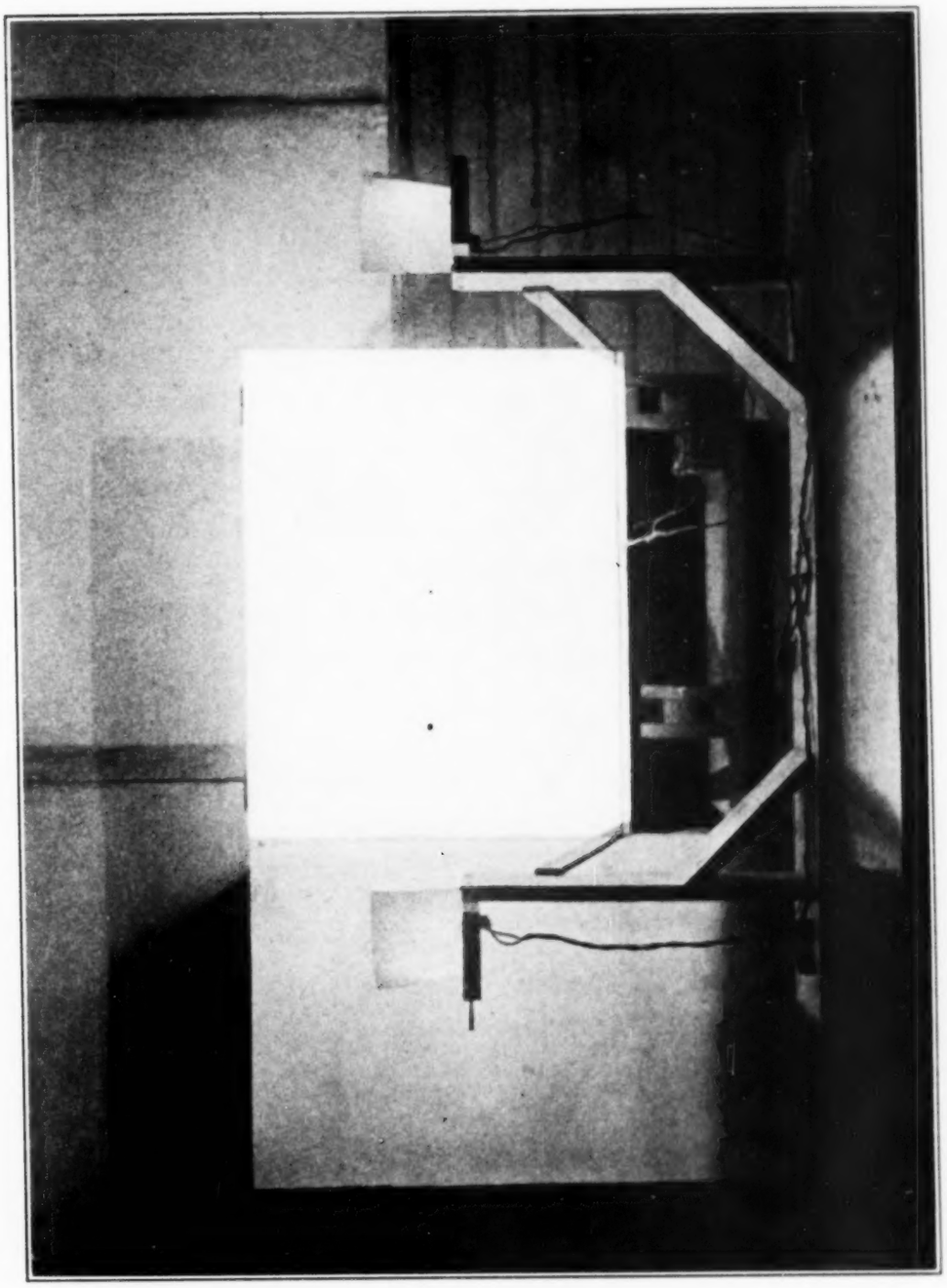


FIG. 1. General view of the apparatus, about as seen by the subject.

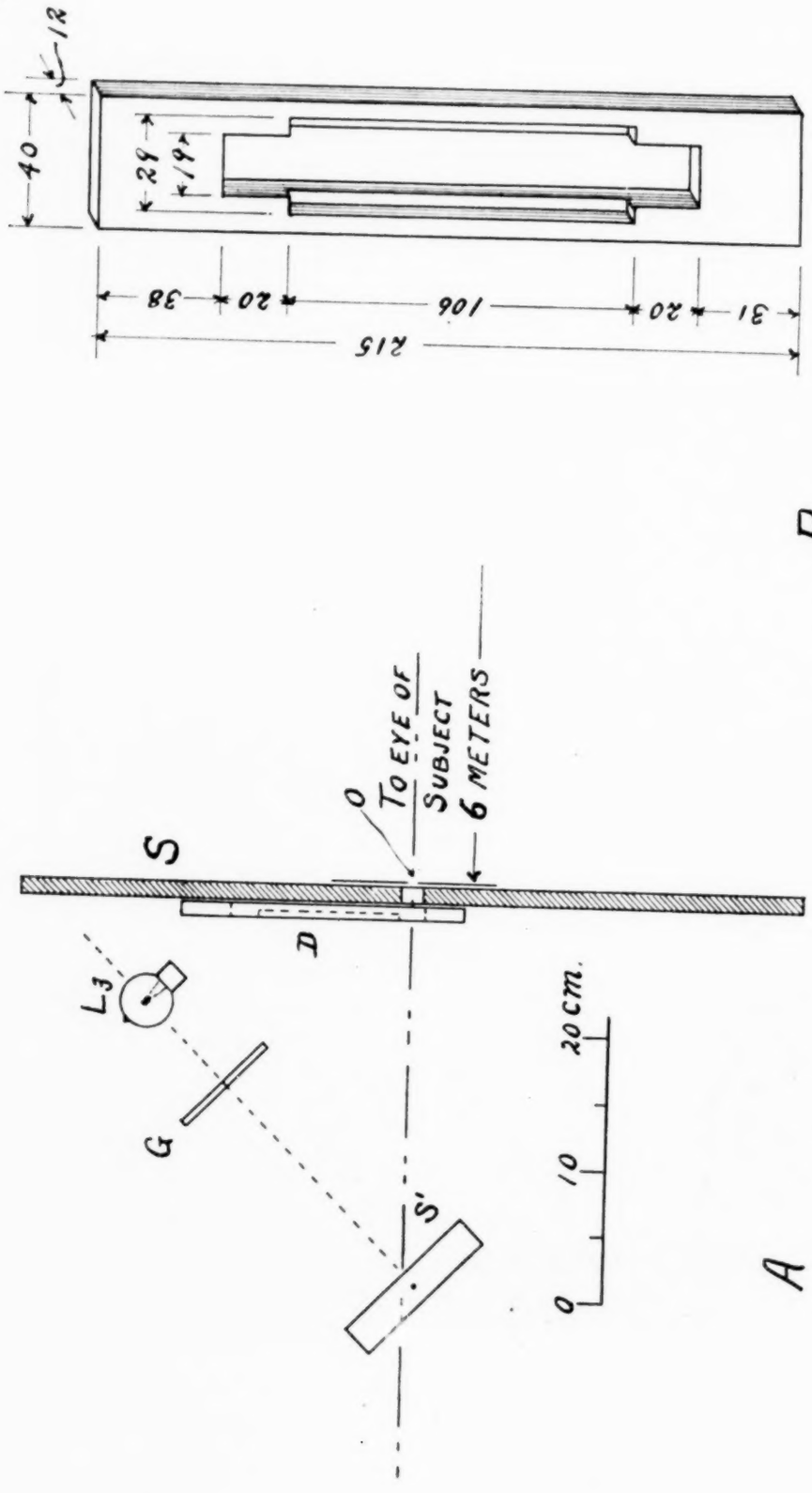


FIG. 2. *A*. Diagram of the apparatus. *B*. Detail of the drop-frame (*D*), with dimensions in millimeters.

ance, a black dot. Experimentally, this condition was to be effected for very brief and measurable intervals of time. A gravity drop-frame was constructed, indicated at *D*, Fig. 2, and arranged so as to fall a fixed distance, in such a way that the aperture was not covered at any part of the drop, and was hence completely invisible to the subject when the frame alone was dropped. A detachable blind could be fitted into the frame to be carried with it in the fall and to pass behind the aperture, cutting off, during the time of passing, the light which had been reaching the eye of the subject from the back screen. This device was so constructed that the upper edge of the blind passed the aperture exactly at the instant when 115 mm. fall, from the starting-point, had been accomplished, the lower edge having covered the aperture a brief interval of time before this. Thus the time of darkening of the aperture depended upon the height of the blind.

The heights of the various blinds were computed to give a geometric series of time intervals corresponding to a series of numerical designations, according to the relation:

$$\text{time} = 200 \times (\tfrac{1}{2})^{N/8}$$

where N is the number of the stimulus and the time is expressed in units of 0.001 second (σ). Thus N, aside from being a convenient numerical designation, has also a definite relation to the time-interval, and fractional values of N are intelligible by means of the formula. The stimuli actually used are included in Table I., where the time in σ, and the height of the blind in mm. are associated with the stimulus numbers. Blinds were constructed for all the numbers, but it was found by trial more expeditious to increase the interval between the stimuli of a series, so the even numbers were laid aside.

Two apertures of different diameters were used. These were punched in the exact center of cards 5 × 8 inches (127 × 203 mm.) and fastened interchangeably at the center of the face of the screen *S*, especial attention being given to see that the aperture was in the correct relation, as to height, with the drop-frame, and laterally with the fixation-point. A hole in the body of the screen was, of course, necessary. This was 11/16 inch (17½ mm.) in diameter.

TABLE I

THE ARBITRARY SCALE OF STIMULI (STIMULUS NUMBER) THE DURATION OF EACH (TIME, σ), AND THE VERTICAL LENGTH (WIDTH, MM.) OF THE CORRESPONDING BLIND, CALCULATED TO CONCLUDE THE REQUIRED PERIOD OF TIME JUST AS THE DROP-FRAME HAS COMPLETED 115 MM. OF FREE FALL

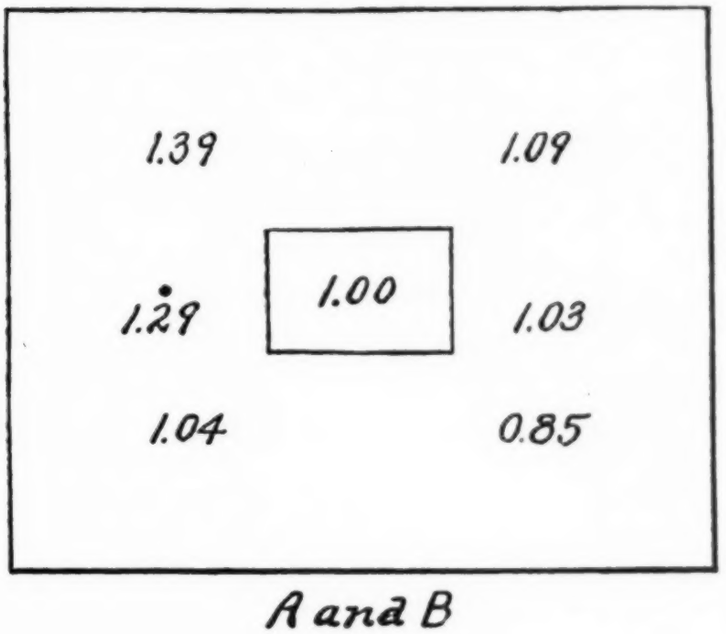
Stimulus, Number	Time σ	Width, Mm.	Stimulus, Number	Time σ	Width, Mm.
7	109.0	105.4	29	16.2	23.1
9	91.7	96.5	31	13.6	19.6
11	77.1	86.7	33	11.5	16.6
13	64.8	76.7	35	9.6	14.0
15	54.5	67.2	37	8.1	11.9
17	45.8	58.4	39	6.8	10.0
19	38.6	50.6	41	5.7	8.4
21	32.4	43.5	43	4.8	7.1
23	27.3	37.3	45	4.1	6.0
25	22.9	31.9	47	3.4	5.1
27	19.3	27.1	49	2.9	4.3

The diameters of the two apertures were measured from the cards actually used, twice in each of the four diameters at 45°, by the help of a microscope with a vernier micrometer stage and a micrometer eye-piece. The vernier read to 0.1 mm., and the measurements so made checked well with measurements similarly made from a pair of cards punched at the same time with the same punches, but never used. The average diameters were found to be:

	Cards Used	Not Used (Check)
A and *C*	4.09 mm.	(4.11 mm.)
B and *D*	4.80 mm.	(4.78 mm.)

The corresponding areas are: *A* and *C*, 13.138 sq. mm., *B* and *D*, 18.096 sq. mm.

In order to show whether sensitivity was appreciably modified by minor differences in the brightness of areas about the stimulus area, two slips of sheet metal were so placed that by their shadows the light from each of the pair of lamps was cut off from a portion (something less than half) of the main screen nearest to it as indicated in Fig. 3, leaving a central vertical band unshaded, sufficiently wide to make sure that the margin of the aperture was not touched



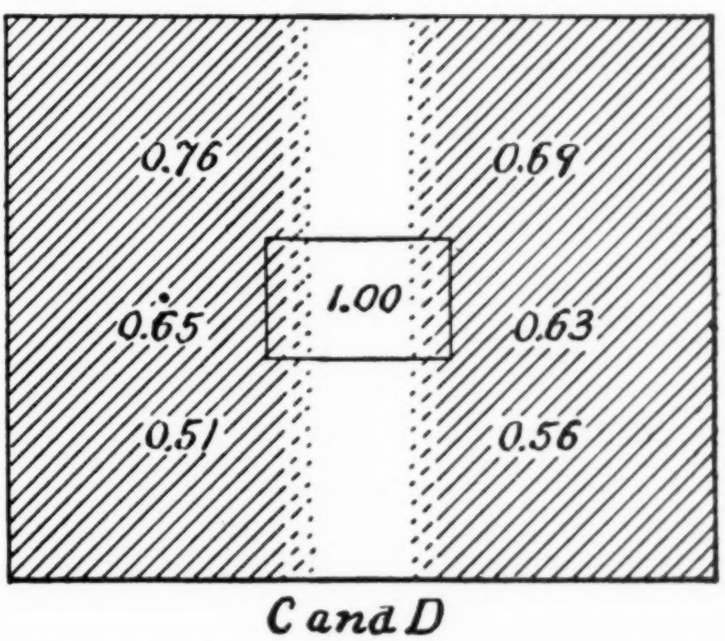


FIG. 3. The relative photometric brightness at various points on the screen, and the distribution of the shadows in cases *C* and *D*.

by the shadows. The change in the distribution of light is numerically shown in the figure, which will indicate that the middle and upper parts of the screen were darkened to the extent of 40 to 60 per cent., the lower part only 30 to 50 per cent. of the central brightness. The shadows were used in the cases under the heads *C* and *D*. The four experimental conditions are thus summarized:

	Aperture	Shadows
A	small	absent
B	large	absent
C	small	present
D	large	present

The screen was viewed by the subject at a distance of 6 meters, the position of his head being fixed by a Troland head rest. Fixation was made upon a point on the screen marked by a black-headed tack, 21 cm. (2° in the visual field) directly to the left of the aperture. The subject released the drop-frame by touching a telegraphic key, conveniently under his hand on the table to which the head rest was clamped. The center of the screen was kept as nearly as possible at a brightness equal to that of the test plate with 3 foot-candles (32.3 meter candles) illumination upon it, which was (the reflection coefficient of the plate being 0.722)

$$\frac{32.3 \times 0.722}{\pi} = 7.42$$

candles per square meter. Readings were taken just before and at the close of each series, and their mean was recorded as the exact value for that series. Photometric measurements were made with a Macbeth illuminometer.

Procedure

The current was adjusted so as to give as nearly as possible the standard photometric brightness at the center of the screen. This was done with the help of the photometer, and the actual reading was recorded. The tendency to a slow and progressive change in the current was found to be minimized by so adjusting the rheostats that the battery

was discharging into the line at the rate of two or three tenths of an ampere. The back screen was then adjusted to equal the main screen in brightness, *i.e.*, so that the aperture disappeared for the subject. To accomplish this he sat with one eye in the line of experimental vision, the other closed, and at a distance of about $1\frac{1}{4}$ meters, while the experimenter tilted the back screen until the opening was as nearly as possible invisible. If the experience of the subject were inadequate to make this method expedient, the experimenter performed the adjustment himself, and afterward had the subject pass upon it. The absence of noticeable color difference made this method unobjectionable. The subject then took his place at six meters' distance and the series was begun. At the close of the series a second photometric measurement was made and recorded as before. Four such series, under conditions *A*, *B*, *C*, and *D*, in various orders, were run at one sitting, and occupied about an hour.

The choice of a psycho-physical method to be used in such work as this is largely a matter of excluding theoretically and practically objectionable features, and the discussion of the considerations which led to the choice and adoption of the one here used, and to the present mode of treatment of the results, would be too long to be included in the present communication.

There is comparatively little to be found in the literature upon the method of serial groups,[1] yet in the eyes of one who is interested in psycho-physiology rather than in introspective psychology, this has an overwhelming advantage over other psycho-physical methods in that it provides an immediate practical check on the subject in requiring him to react differentially to the stimuli and to the associated blanks in the same group.

The groups used consisted of 5 equal stimuli and 5 blanks, presented in shuffled order. For the blanks, in order that the motions of the experimenter should not be made the

[1] See Stratton, G. M., *Psychol. Rev.*, IX., 1902, pp. 444 to 447, and Thomson, G. H., *Br. Jour. Psychol.*, V., 1912–13, p. 204 ff. and p. 398 ff. Also Myers, 'A Textbook of Experimental Psychology,' London, 1909, p. 209; same, 2d edition, 1911, Part I., pp. 196 to 197.

basis of reactions, a small horseshoe-shaped metal device was used to replace the blind, fitting into the drop-frame in a similar way, but so formed that at no time during the fall of the drop-frame did any part of it intervene between the aperture and the back screen. A fairly large stimulus was used in the first group, the number of the initial stimulus being later determined by previous experience. The subject had only to fixate the designated mark when the signal 'ready' was given, release the drop by pressing the telegraphic key, and give his answer 'yes' or 'no' as to the adjudged momentary presence of the dot. If upon the first group a perfect score were given, the next group, involving a stimulus of one stage shorter duration, was given without pause; otherwise the next longer stimulus until a perfect score was rendered. The first perfect score being the starting point, consecutive groups were presented with stimuli diminishing step by step until a zero (or negative) score was rendered. This completed the series.

The descending order alone was used. The score for a particular stimulus was simply the number of 'yes' answers given among the five answers to the stimuli, minus the number of 'yes' answers (if any) given among the five answers to the blanks, and could possibly be anything from 5 to -5. Some subjects rarely failed to give correct interpretation to the blanks and rendered a zero score by replying 'no' throughout the group. Others showed greater tendency to fail on the blanks and by the method used all were quantitatively 'docked' therefor, resulting sometimes, but not frequently, is a score of -1 or -2 at the close of the series. The reason for this mode of rating should be obvious: we have no way of knowing whether the subject sees the stimulus except as we may infer it from the fact that his reaction to it is different from his reaction in the absence of it. We can agree with Myers that the positive reactions to the 'catches' are interesting psychologically, but we cannot agree with his statement that they are to be left out of account in the computation. The stimulus has been effective only in so far as the positive reactions to it have exceeded the positive reactions to the

blank. The negative score is not troublesome if we remember that it is (so to speak) the obvious consequence of bad luck in guessing, and that in the long run this method of computing causes it and other unlucky guesses algebraically to offset the results of lucky guessing not otherwise detectable.

Estimating the threshold from the serial scores was accomplished by determining, by linear interpolation, that value of stimulus in terms of scale-number which corresponded with a score of $2\frac{1}{2}$ (50 per cent. of a maximum of 5). In cases of inversion, where more than one such point was to be found, the first crossing of the 50 per cent. point was interpolated (*a*) reading the series in the descending direction and (*b*) reading the series in the ascending direction. The mean of (*a*) and (*b*) was then accepted as the threshold for that series.

The performance of four series, involving the four conditions *A*, *B*, *C*, and *D*, occupied about an hour. The order of these was systematically varied from day to day.

The three subjects used are described as follows:

B.—A woman, age about 21, typist. Refraction not determined, but does not wear glasses nor show other evidence of visual defect. An ideal subject, in the fact that she renders prompt and definite judgments.

C.—Captain in the Medical Corps, U. S. Army, specializing in sense physiology, age 47. Astigmatism, well corrected, and moderate presbyopia. Vision, without glasses R. 20/50, L. 20/50 +. Wears: R.: + 1.75 cyl. ax. $92\frac{1}{2}°$, V. = 20/15; L.: −0.25 sph. with + 1.75 cyl. ax. $92\frac{1}{2}°$, V. = 20/15; with + 1.00 sph. each eye, for near vision. As a subject, somewhat slow to react, but with experience in such work.

L.—A woman, age 28, psychologist. Vision 20/20 + 2/8 each eye. Does not wear glasses. Refraction, without mydriatic: R.: + 1.00 sph. with + 0.25 cyl. ax. 82°, V. = 20/15; L.: + 0.50 sph. with + 0.25 cyl. ax. 112°, V. = 20/15. Exophoria, 2 prism diopters at 6 meters. Experienced as a subject in psychological work.

The amount of experience as subject in this identical problem, prior to the work here recorded and incidental to

the development of the method, is various for these three. *B* had about the equivalent of 12 series, *C*, about 30 and *L*, about 20. As nearly all of these were run before the method came into its present form, it is only in a rough way that an equivalence can be estimated.

Before computing the results a few of the series were deleted: (3 in the case of *C*, 1 in the case of *L*) where there was suspicion of an error in technic which did not permit of revision, or obvious disturbance of the subject, or, in one case, where the scores of the series gave evidence of some anomalous condition in the subject. In this last it turned out that the inclusion of this value would not have significantly altered the average.

The results of the remaining series were averaged, and in Table II. are given: the mean threshold (N) and its probable error (E_N), and the number of terms (series) entering into the mean threshold (p).

Further, to each group of results (*A*, *B*, *C*, or *D*) Chauvenet's criterion was applied, which resulted in further eliminations (1 in the case of *B*, 3 in the case of *C* and 2 in the case of *L*). The averages from the remaining series are given under (*a*) in Table II.

Results and Discussion

The first question to be examined in the light of these results is the hypothesis implied in one of the introductory paragraphs of this paper. In these results, do the threshold times of exposure and the areas of aperture give equal products for the two cases? If it is true that they do we should find the relation: $a_1t_1 = a_2t_2$, or $a_1/a_2 = t_2/t_1$; in which a_1 and a_2 are the areas of the two apertures and t_1 and t_2 the corresponding times of threshold exposure experimentally found. But it follows from the formula: $t = 200\ (\frac{1}{2})^{N/8}$ that:

$$\frac{t_2}{t_1} = \left(\frac{1}{2}\right)^{(N_2 - N_1)/8}$$

N_1 and N_2 being the two corresponding thresholds as found

in terms of the stimulus scale. Hence:

$$\left(\frac{1}{2}\right)^{(N_2-N_1)/8} = \frac{a_1}{a_2} = \frac{18.096}{13.138} = 1.3773,$$

TABLE II

MEAN THRESHOLDS IN UNITS OF STIMULUS SCALE

The average results, for each of the three subjects. The small opening has an area of 13.138 sq. mm., the large one 18.096 sq. mm., both seen at 6 meters distance, at the center of a white screen 60 by 76 cm., fixation 2° to the left of the (central) opening.

N.—Average threshold, arbitrary scale. Compare Table I.

E_N.—Probable error of the same.

p.—The number of series upon which the above are based.

Small Opening				Large Opening		
N	E_N	*p*	Subject	*N*	E_N	*p*
A. No shadows				*B*. No shadows		
22.63	0.32	(18)	.....*B*.....	26.05	0.19	(18)
26.31	0.18	(21)	.....*C*.....	29.85	0.37	(21)
22.37	0.29	(20)	.....*L*.....	26.01	0.18	(21)
C. With shadows				*D*. With shadows		
22.79	0.31	(18)	.....*B*.....	27.14	0.21	(18)
26.24	0.24	(21)	.....*C*.....	29.17	0.27	(22)
22.17	0.17	(21)	.....*L*.....	26.96	0.18	(21)

(*a*) SAME AS ABOVE. HUGE DEVIATIONS ELIMINATED BY CHAUVENET'S CRITERION

A. No shadows				*B*. No shadows		
22.63	0.32	(18)	.....*B*.....	26.05	0.19	(18)
26.33	0.14	(19)	.....*C*.....	29.85	0.37	(21)
22.63	0.27	(19)	.....*L*.....	26.18	0.17	(20)
C. With shadows				*D*. With shadows		
22.79	0.31	(18)	.....*B*.....	27.32	0.18	(17)
26.05	0.22	(20)	.....*C*.....	29.17	0.27	(22)
22.17	0.17	(21)	.....*L*.....	26.96	0.18	(21)

from which we obtain, by means of logarithms:

$$N_1 - N_2 = 3.695.$$

This is the difference, on the stimulus-number scale, between the time thresholds for the smaller and larger apertures respectively, which is demanded by the hypothesis that the product, area multiplied by time, shall be constant for the threshold.

How far the experimental results go toward confirming the hypothesis from which the foregoing is, a priori, derived,

will be seen by a glance at the first three columns of Table III., where the average experimental differences are stated with their respective probable errors. The elimination of the widely deviating results by means of Chauvenet's criterion, it will be seen (*a*, Table III.) has not significantly altered the result. On the average, the difference in scale-units is 3.77, with a probable error ± 0.14, or (*a*) with application of Chauvenet's criterion, 3.82 ± 0.14. The deviations from 3.695, the *a priori* value, being respectively 0.075, and 0.125, both lying well within the limits of the probable error. It is to be noted that there are items entering into the final average which depart rather widely from the anticipated result. These are under "*D–C*," Table III., the comparison of the two apertures with the shadows on the screen. The departures of the experimental differences from the value 3.695 are here, for the several observers: *B*, 0.655 ± 0.37; *C*, − 0.765 ± 0.36; *L*, 1.095 ± 0.25, all of which are seen to be larger than their respective probable errors. In connection with this fact, the further fact is to be noted, that the results in the last three columns of the table all indicate that the presence or absence of the shadows was without significant effect, *except* in the cases under *D–B* (shadows compared with no shadows, larger aperture) where the differences are too large, relatively to their probable errors, to be considered insignificant. These differences, further, are all in the same direction as those just pointed out under *D–C*, each for each, and taken together, the two sets of results might be considered to indicate that the three observers differed most widely from each other in the case of the large aperture with shadows on the screen (condition *D*) since this is the experimental condition common to the two sets of differences, each of which, in detail, deviates from the general average in a corresponding way. This can be looked upon as presumptive but not as a definite conclusion, since the differences quoted are not large enough to put the matter beyond doubt.

So far, this discussion has been limited to the consideration of the effect, upon the time value of the threshold, of the two experimental variables purposely introduced. These are:

TABLE III

EXPERIMENTAL DIFFERENCES, IN UNITS OF STIMULUS SCALE

The differences, on the arbitrary scale, due to the use of the large or small opening, and those due to the presence or absence of shadows. Compare Table II.

d.—Experimental difference, arbitrary scale.

E_d.—Probable error of the same.

p.—Weight of the result, the weight of a single series being unity.

Large *vs.* Small Opening				Shadows *vs.* No Shadows		
d	E_d	p	Subject	d	E_d	p
B–A. No shadows				*C–A.* Small aperture		
3.42	0.37	9.00	.....*B*.....	0.16	0.44	9.00
3.54	0.41	10.50	.....*C*.....	−0.07	0.30	10.50
3.64	0.35	10.24	.....*L*.....	−0.20	0.34	10.24
3.54	0.22	29.74	... Mean ...	−0.05	0.21	29.74
D–C. With shadows				*D–B.* Large aperture		
4.35	0.37	9.00	.....*B*.....	1.09	0.28	9.00
2.93	0.36	10.74	.....*C*.....	−0.68	0.46	10.74
4.79	0.25	10.50	.....*L*.....	0.95	0.25	10.50
4.00	0.19	30.24	... Mean ...	0.41	0.20	30.24
All results				All results		
3.77	0.14	59.98	... Mean ...	0.19	0.14	59.98

(*a*) SAME AS ABOVE. HUGE DEVIATIONS ELIMINATED BY CHAUVENET'S CRITERION

B–A. No shadows				*C–A.* Small aperture		
3.42	0.37	9.00	.....*B*.....	0.16	0.44	9.00
3.52	0.39	9.97	.....*C*.....	−0.28	0.25	9.74
3.55	0.32	9.74	.....*L*.....	−0.46	0.32	9.97
3.50	0.21	28.71	... Mean ...	−0.20	0.20	28.71
D–C. With shadows				*D–B.* Large aperture		
4.53	0.35	8.74	.....*B*.....	1.27	0.26	8.74
3.12	0.34	10.47	.....*C*.....	−0.68	0.46	10.74
4.79	0.25	10.50	.....*L*.....	0.78	0.24	10.24
4.12	0.18	29.71	... Mean ...	0.40	0.20	29.72
All results				All results		
3.82	0.14	58.42	... Mean ...	0.10	0.14	58.43

the area of the stimulus-opening; and the presence or absence of shadows upon the screen. In addition to these, there are three other variables, incidental to the experimental procedure, which, including the principal variable, namely the threshold itself, are listed as follows:

1. The time threshold. This is the stimulus number reduced, for the purpose of correlation, to an intercomparable

value by expressing the result of each series in terms of the mean of the group taken under identical conditions. Symbol, T/M.

2. The ordinal number of the series in the group of four taken at a sitting.

3. The ordinal of the sitting in the group of 18 to 22 taken under identical conditions.

4. The mean photometric brightness of the field immediately surrounding the test-stimulus.

In what follows these quantities are designated by subscripts corresponding to the numerals above.

These four variables are correlated by Pearson's method,[1] two and two, and from the six correlation coefficients of the zero order, so obtained, the partial coefficients of the second order were computed. These, with their probable errors (E_r), are as follows:

	Subject					
	B		*C*		*L*	
	r	E_r	r	E_r	r	E_r
$r_{12.34}$	.037	.080	.098	.074	−.362	.065
$r_{13.24}$	−.046	.080	.082	.074	.125	.074
$r_{14.23}$	.311	.072	.115	.076	.174	.073

Similarly the standard deviations of the four variables, of the zero and second orders are:

	B		*C*		*L*	
	Zero Order	Second Order	Zero Order	Second Order	Zero Order	Second Order
1	0.065	0.062	0.057	0.056	0.053	0.049
2	1.11	1.07	1.13	1.12	1.12	1.04
3	5.2	5.0	6.4	6.3	6.0	5.9
4	0.12	0.11	0.11	0.11	0.087	0.085

[1] As described by Davenport, C. B., 'Statistical Methods,' 3d ed., New York, p. 44. The mathematics involved in the discussion is treated by Yule, G. U., 'Theory of Statistics,' London, 1919, Chap. 12.

And the characteristic equations derived from these, for the three subjects, are stated as follows:

$$B: \quad x_1 = 0.002\,x_2 - 0.0006\,x_3 + 0.18\,x_4 \qquad E = \pm 0.042$$
$$C: \quad x_1 = 0.005\,x_2 + 0.0007\,x_3 + 0.06\,x_4 \qquad \pm 0.038$$
$$L: \quad x_1 = -0.017\,x_2 + 0.0010\,x_3 + 0.10\,x_4 \qquad \pm 0.033$$

In these equations, the various x's have reference to differences or variations in the corresponding variables—or perhaps better, we may say that x represents the deviation of the variable from the mean of all its experimentally measured values, in units the same as those in which the corresponding quantity is expressed.

If we wish to estimate the extent to which x_1 is influenced by the deviation of any one of the other variables, say x_2, from its mean value, we must substitute that deviation of x_2 for x_2 in the equation and put x_3 and x_4 equal to zero. From inspection of the equations, it will thus appear that x_2 is most significant in the case of subject L. An idea of its importance in these results may be gained by substituting for x_2 its standard deviation (1.12) and we have $x_1 = -0.017 \times 1.12 = -0.019$. Which is to say that in this case, fluctuations in the value of T/M (x_1) are introduced by the fact that subject L gave higher results early in the experimental sessions and vice versa, and that the effect of these fluctuations upon her results are represented by a standard deviation of T/M equal to 0.019. This is equivalent to 0.42 or 0.50 in "Stimulus Number" (Table I.) according as we refer it to the threshold obtained with the small opening (average 22.27, Table II.) or the large opening (average 26.48). A representative range of fluctuation due to this cause might be taken as twice this or roughly one number on the scale, if we look upon the fluctuations as centering at the mean, and characteristically extending by an amount equal on the whole to the standard deviation in either direction therefrom. When we investigate in the same way the serial number of the day, the same subject shows the largest deviation: $0.0010 \times 6.0 \times 2 = 0.012$, indicating that the representative practice effect for the whole period of experimentation is small,

less than $\frac{1}{3}$ of one scale unit. This is, perhaps, not surprising, in view of the fact that each of the three subjects had had practice with the method before any of these recorded results were taken.

The deviations of the photometric value of the test-field, x_4, have not, except in one case, produced any noteworthy disturbance in this work, but such disturbance as is shown, taken together with other considerations, makes the photometric control of the conditions a precaution carefully to be considered. From the characteristic equations, we have, similarly to the foregoing, the disturbance due to photometric fluctuation:

	In Terms of T/M	In Scale-Units
for B, 0.18 × 0.12 × 2 =	0.043	0.97 to 1.14
C, 0.06 × 0.11 × 2 =	0.013	0.34 to 0.38
L, 0.10 × 0.087 × 2 =	0.017	0.38 to 0.45

While, in scale-units, these deviations are not larger than the deviations due to variables 2 and 3, *i.e.*, those defining the place of the series in the experimental order, it must be emphasized, first, that the variations in the photometric values themselves (x_4) are small, being no more than the unavoidable variations in the adjustment of the apparatus to an exact value, but they are still large enough to measure. The largest value of the standard deviation is 0.12 apparent foot-candles (in the cases of B and C) which means that while 3 apparent foot-candles was the brightness aimed at, the actual brightness fell about as often within the limits 2.92 to 3.08 ($3.00 \pm 0.6745 \times 0.12$) as it fell outside of these limits. These limits are the exact value attempted, plus and minus its probable error computed from the actual results.

The second point to be emphasized is, that if this measure of retinal sensitivity is to be used as a test, the apparatus must be checked against a standard light-source, by means of a photometer, and corrected as often as necessary as the work proceeds. The mean coefficient of x_4 in the three characteristic equations is 0.11 and the corresponding coefficients of correlation (14.23) are large enough to be signi-

ficant. This means that within the present limited range of the actual photometric settings, the measure of sensitivity of the individual changed at the rate of 11 per cent. (1½ to 3 numbers in the various cases) per apparent foot-candle. While it is not correct to extend the application of this rate of change beyond the range for which it was actually found to exist, it must nevertheless be remembered that the voltage in the usual lighting circuits is often a highly variable quantity; that the percentage change of the candle-power of an electric lamp is several times the corresponding percentage change in voltage; and that an individual lamp operated at its rated voltage is a changing and not a constant source. Such lamps are usually designed and rated to operate 1,000 hours with 20 per cent. drop in candle-power during that period. Twenty per cent. of the present screen brightness is 0.6 apparent foot-candles, which would, on the average, condition a drop of 0.066 in T/M, or a drop of nearly 2 scale-units in retinal sensitivity. And this is nothing as compared with the errors that would have been introduced by depending upon a line-voltage characterized by such fluctuations as those existing at Mitchel Field at the time this work was done.

Another consideration, which led to the installation of the motor-generator and battery used in the present work, was the possibility of errors due to the use of the alternating current. Although ordinarily appearing to give a steady light, electric lamps, and especially those of the lower wattages and therefore more slender filaments, undergo rapid fluctuations in candle-power synchronously with the alternations of the current. On a 60-cycle current the dim (or bright) phases occur at the rate of 120 per second, or at intervals of 8.3σ. Stimulus number 22 has a duration of 29.7σ, number 29, 16.2σ. It seemed clear in advance, that the fluctuations in the light from a lamp on the alternating circuit might introduce errors, variable in amount according to the exact phase of the current in which the shutter was dropped. The use of the direct current evaded this dubious condition; and the use of automobile lamps, designed for low voltage and high current, and consequently having filaments too coarse to readily follow, in

temperature, any sudden and slight fluctuations of the current, was especially favorable from this standpoint.

Summary

1. A threshold method of measuring retinal sensitivity is proposed, by which a stimulus of very small and fixed extent is exposed for a very short measured time. The stimulus is physically a negative one, by which is meant that it appears as a black dot upon a white screen.

2. The psycho-physical method of serial groups was used, each series of groups furnishing one datum. The basis of the conclusions is 240 such series, about equally divided among the three subjects.

3. It was found that the product of the time of exposure multiplied by the area of the stimulus was constant, on the average, at the threshold. This applies to the two apertures used, of 13.138 and 18.096 square millimeters' area respectively, observed at 6 meters' distance.

4. For the several observers, the average threshold time, reduced to its equivalent with a standard opening (area = $10\sqrt{2}$ square millimeters) was found to be: B, 25.7σ; C, 19.5σ; and L, 26.2σ.

5. Shadows, covering the major part of the screen, but not the working area immediately about the stimulus, by which 40 to 60 per cent. of the light was cut off, did not significantly alter the time necessary for effective stimulation.

6. The place of the series in the succession of the usual four run at one session did not appear, except in one case, to be of significant effect upon the threshold time. The correlations were dubious in the other two cases. In the one case in question, a manifest hyperopia of one diopter and of one half diopter was demonstrable in the two eyes respectively, and sensitivity appeared to grow less during the progress of the day's series.

7. The serial place of the day in the whole course of experimentation was of negligible import, except possibly in the case of the same observer, where the coefficient of correlation (second order) was 0.125 ± 0.074, and no more than a minor effect upon the result was indicated.

8. There appeared to be a fairly definite and constant correlation between the threshold time and the unavoidable but measurable variations in the photometric brightness of the screen, in the direction of decreased threshold time with increased brightness. This was minimized in the experimental work by careful measurement and adjustment of the brightness. This result justifies the photometric precautions used and indicates the absolute necessity of careful photometric control in any application of this method of retinal sensitivity measurement.

IMPROVEMENT IN BRIGHTNESS DISCRIMINATION AND ITS BEARING ON A BEHAVIORISTIC INTERPRETATION OF PERCEPTION

BY EDWARD S. JONES

Oberlin College

A good deal has been written in support of the necessity of a reaction (*i.e.*, some type of muscular response) in every perceptual experience. The emphasis on reaction can be traced at least back to Dewey in his 'Reflex Arc Concept' article,[1] and is well summarized in Washburn's 'Movement and Mental Imagery.' This tendency, however, has not seeped into many of the current textbook treatments of perception. Is it perhaps because there is little experimental evidence for it, and because of the fact that in such discriminations as those of color or brightness it is hard to explain a difference in perception in terms of reaction?

The following experiment tends to support the belief that even our perception of brightnesses involves a reaction phase; and that the improvement of that reaction is the basis of the improvement in discrimination in that perceptual field. (By improvement in reaction is meant the building up of differentiated reactions.)

The experimental material was a set of shades of gray running from white to black—each shade barely distinguishable from the one next to it. Three observers agreed as to the exact order of sixty of these shades of brightness, and the shades were so numbered on the back from No. 1 (white) to No. 60 (black). This made up the testing series. There was also a 'standard' series of five shades presented before the subject was asked to estimate the numbers of various shades in the testing series. The standard set was made of the shades Nos. 1, 15, 30, 45 and 60, and so numbered below, so that each subject could have a complete survey of the

[1] *Psychological Review*, Vol. 3, 1896.

range of these grays and keep in mind just how to number those seen in the testing series.

The standard was presented each time for 10 seconds, after which 10 of the shades in the testing series were presented in succession, these ten distributed at random throughout the series. The subject merely put down the number which he believed corresponded to the brightness number of each shade of the test series as it was presented. Two such series of ten shades, each introduced by showing the standard, constituted a day's testing for a subject, and he was then allowed to note his errors. Each person's ability to discriminate brightnesses was measured by finding the average deviation of each gray's recorded brightness number from its true number.

Two different groups of subjects were tested, the first to be discussed a control group each subject of which was given twenty shades one day and the same twenty two weeks later. The average deviation of the twelve subjects the first day was 4.8 shades, and later 4.1, showing an improvement of .7 of a shade. These subjects were unselected from an elementary class in Psychology. Eight of the twelve showed improvement, while two remained the same and the other two showed slightly poorer records the second time than the first.

The second group, of ten subjects, were advanced students in a class in educational psychology, several of whom had had a course in experimental psychology. They had been reading Thorndike's surmise that any type of mental function could be improved if interested practise were applied. Further they had received from the writer the suggestion that probably all discriminations depended upon reactions that have been made specific, that we are confused in our perceptions only to the extent that we have not developed reactions which are definite one from another.

This group was given the same series of twenty shades twice, as in the case of the control group, but in between the subjects were given four days of practise. They were also asked at the beginning and at the end of the testing to record any devices they were using as aids in their discriminations,

and any muscle strains that appeared or other adjustments which might be of influence. Care was taken to give an entirely different series of grays for the various practise days than that used for the testing of improvement, so that the order of arrangement could not be detected by the subjects.

The results of ten subjects tested accordingly are as follows: Average deviation of initial series of twenty shades (*i.e.*, deviation of estimated from true numbers), 4.0 shades. Average deviation of same twenty shades after five days practise, 2.7 shades. This is of course a marked improvement, as the later figure must be near the average physiological limit for such a function.

The table below records the deviations made by subjects before and after practise, and it also summarizes briefly items given in the introspective reports of subjects. Only one subject did not improve, a girl with an unusually low score at the beginning and who reported clear visual imagery. This subject said she seemed to have less and less confidence in her judgment as she went on.

In the case of 6 of the 7 subjects who improved considerably, one shade or more, definite muscular strains were observed. The other subject of this group reported no variety of muscular reaction, though his final record was superior to that of the others. However when questioned further he replied that he had developed a 'system' which seemed to work. This was to bring his eyes to rest each time before glancing at a shade (so far as any definite fixation was concerned), then to make a number of quick glances, closing his eyes before each. It is quite probable therefore that his mechanism of reaction involved muscles of accommodation or convergence.

Associations, another method of reaction, were apparently useful (*i.e.*, calling a specific gray slate color, or thinking of a black as belonging a certain distance down a well).

Clear visual imagery of the standard was effective, but perhaps not as significant as would be thought. The clearness of this imagery was not enhanced as practise went on and as discrimination improved. The suggestion is clear

from the reports that a visual image of the standard is really in terms of a reaction; that perhaps all imagery is fundamentally a mode of reaction. What was frequently referred to as 'holding the standard in mind' is really maintaining certain muscular adjustments, usually of the eye muscles, so that they can be later compared with other reactions. The muscle strains used in connection with these visual images may be the only ones used, though it is quite possible to work up other 'systems' of reaction (such as general body strain) to hold or recall the position of a shade in a series.

Practise with such a system involves the same situation as is present with any form of motor learning. There are random excursions and a more or less unconscious gradual adoption of a technique. Confidence of success is low and unrelated to actual success. *E.g.*, the two subjects 8 and 9 (in the table) said they gained in confidence considerably, while the subjects 2 and 4 claimed to have developed very little confidence even at the end.

It is probable that practise in emphasizing a system, or method of reaction, is valuable in improving such a perceptual discrimination. As in the case of all learning, improvement is better if we are conscious of making correct reactions. The reactions incident to ordinary visual imagery are on the other hand of long standing, and usually beyond the scope of consciousness. Practise may have little influence here, except as some other system is developed to corroborate or confuse the visual image.

The perceptions of brightnesses, or of colors (for similar experiments have been carried out with colors), seem to resolve fundamentally into methods of reacting. With colors the reaction is more apt to be a verbal one, the name of the color; and the discrimination of unfamiliar tints therefore takes a longer time. But without some muscular adjustment, or tightening, there would be no machinery for the discrimination of one stimulus from another. Muscles are the organs of movement and change. They retain habits and images. Nerves are perhaps connectors and conductors only.

INDIVIDUALS ARRANGED IN ORDER OF THEIR IMPROVEMENT

Subject	Ave Dev. 1st 20 Times	Ave Dev. after 5 Practises	Introspections as to Imagery and Types of Reaction Experienced
1	5.5	2.2	Noticed eye and general body strains. Used associations (medium gray = slate). Fair visual image of standard without improvement after practise.
2	5.5	2.8	Clear visual image of standard from beginning. Eye movement noticed. All body muscles tend to tighten with light shades.
3	3.8	2.1	Visual image fair, but faded quickly. Eye muscles seemed to tighten with dark shades.
4	3.7	2.0	Visual image was only fair and became no better. Names were used for different shades. Some eye strain observed.
5	3.1	1.6	Visual image of the standard, good. No general body strain noticed. Rapid glancing at stimulus of value.
6	4.0	2.7	Visual image, fair. General body strain as shades were darker. Some associations used.
7	3.9	2.8	Visual image very poor. Eye strains noticed. Rigid fixation on the stimulus helped.
8	3.7	2.9	Visual image, fair. Some eye and forehead strain noticed as shades were darker. Not always present however.
9	3.9	3.2	Visual image, very poor. Some tendency to tighten with dark grays. Otherwise no strains.
10	2.5	4.3	Used visual image entirely. Very clear, but seemed to lose confidence in it. No strains observed.

PHYSICAL ATTRACTIVENESS AND REPULSIVENESS

BY F. A. C. PERRIN

University of Texas

A study of the physical characteristics of human beings has its place in psychology as well as in the various interests represented by art, anthropology, anatomy and physiology. If we may include under this heading, not only static and anatomical items, but certain forms of expressive behavior, personal habits and mannerisms, and qualities of the voice, we will find additional justification for the claim just made. The published accounts dealing even indirectly with this group of factors are extremely meager, both in scope and in amount. Until the recent appearance of Dunlap's *Personal Beauty and Racial Betterment*, they were to be found, only after diligent search, in the writings of Ellis, Thomas, Freud, and a few others. It is the purpose of the present paper to suggest a few theoretical considerations, and to submit the results of a statistical investigation, both concerned with this general subject.

The physical characteristics of an individual may be studied from two distinct points of view. They may, in the first place, be considered with reference to their possible diagnostic values. While this does not fall within the scope of the present investigation, it deserves passing mention. In spite of the wild claims of the professional character analyst, it is possible that physiognomy errs more in its violation of scientific method than it does in its major premise. The psychologist is insistently a seeker after signs; and if they can be found in delayed verbal responses, psychogalvanic reflexes, and systolic manifestations of blood pressure, they may presumably be discovered in those observable aspects of behavior which are intimately associated with emotional and intellectual life. In particular, some of the items enumerated

in a subsequent section of this paper, under the heading of "Expressive Behavior," might well repay serious investigation from this point of view.

Of more direct importance, however, is the fact that the physical characteristics of an individual constitute a large group of the total series of effects produced by that individual upon others.[1] The question is whether or not the total series of effects, or any part of that series, is deserving of psychological attention. And it is, if we are to assume that the stimuli which elicit responses in the human animal are at all worthy of scientific interest. For the human animal responds primarily to social situations; his conditioned reflexes center around people, as well as physical objects; his intellect and skill, even, are largely socialized. Aside from this general consideration is the fact that physical characteristics have their significance for vocational and for individual psychology, and for a science yet to be formulated—the psychology of personality and character.

The statement that people do react definitely to the physical in other people may be made safely without statistical evidence. Most of us respond unambiguously to physical beauty and ugliness, to a pretty face or a well-proportioned body. And these factors are not always made subordinate to intellectual and moral qualifications. Even in Y. W. C. A. posters, we find occasionally that delineations of feminine physical attractiveness prevail over suggestions of goodness and virtue. Just why the physical characteristics of individuals should exert so profound an influence over their associates furnishes an interesting topic of speculation. A list of the factors involved would certainly include sex appeal, and the muscular responses elicited by the manifestations of bodily symmetry, proportion and balance, bodily rhythm and physical strength, grace and awkwardness. The evidence offered in this paper seems to favor sex appeal as the fundamental factor. But whatever the explanation may be, the fact of physical appeal remains as an important aspect of human behavior.

[1] For a discussion of the general point involved, see the beginning chapter of Thorndike's *Individuality*.

With the above considerations in mind, the writer undertook a number of statistical investigations in the psychological laboratory at the University of Texas. He was most ably assisted by a group of advanced students in the department at that institution. These students were well qualified for the work in one essential respect: they were acquainted socially with the large number of students who unconsciously acted as subjects for the investigation. The results here reported represent a survey of the field, rather than an intensive study of any one phase of the subject.

1. *A Rating Chart for Physical Characteristics.*—The first aim of the writer was to obtain an inventory of the elements which operate in positive or negative physical appeal, and this was realized in the formulation of a rating chart for physical characteristics. No special merit, of course, is to be found in a chart of this nature. In itself, it is merely an itemized list of the factors involved, and its value depends upon the purpose for which it is used. The items here enumerated, however, have a certain intrinsic value, inasmuch as they were determined by an actual inductive procedure. The members of the experimenting group were asked to list 25 girls and 25 boys noted for their physical attractiveness, and to list a corresponding group noted for their negative appeal. The subjects were selected from the entire undergraduate body, and they represented, respectively, the extreme cases in the entire range. With the names before them, the judges were instructed to write out all possible characteristics which aroused affective reactions of any sort. These characteristics were then classified, somewhat arbitrarily, and were printed on a four-page folder, in tabular form. Seven columns were provided for check marks, indicating the ratings to be made on any one individual regarding the amount or predominance of the trait or characteristic, and a corresponding set of columns was provided for the ratings on the degree of pleasing appeal of each characteristic. The columns were numbered, and the numbers were defined as follows: 1, Very Low; 2, Low; 3, Slightly Below Average; 4, Average; 5, Slightly Above Average; 6, High; 7, Very High. Complete directions were

given for scoring. The items as classified, with many detailed explanations omitted, are given in the following table:

A. Static Physical Characteristics: Beauty, Size, Proportion, Symmetry, Texture of Hair and Skin, Etc.

I. *Head and Face*

Size of head
Shape of head
Symmetry of features
Heaviness—lower part of face
Skin of face—smoothness
Skin of face—color
Skin of face—freckles
Skin of face—tan
Hair—amount on pate
Hair—amount on face
Hair—darkness
Hair—amount of red
Hair—glossiness
Eyes—size
Eyes—color
Eyes—distance apart
Eyes—large sockets
Eyes—horizontal position
Eyes—puffiness below
Eyes—wrinkles around
Eyes—dark below
Eyes—expression
Eyebrows—amount
Eyebrows—distance apart
Eyebrows—straight
Eye lashes—length
Ears—size
Ears—protruding
Nose—dilate nostrils
Nose—size
Nose—shape
Nose—correct color
Teeth—white
Teeth—regular
Teeth—protruding
Teeth—gap-toothed
Mouth and lips—size
Mouth and lips—color
Mouth and lips—smooth
Mouth and lips—symmetrical
Mouth and lips—same size
Mouth and lips—expression
Chin—size
Chin—shape and position
Chin—dimples
Cheeks—full
Cheeks—wrinkles
Cheeks—dimples
Cheek bones prominent
Forehead—width
Forehead—height
Forehead—shape
Neck—thickness
Neck—length
Neck—uniform diameter
Face—shape

II. *Arms and Hands*

Arms—size
Arms—shape
Arms—length
Elbows—pointed
Elbows—size
Elbows—dimples
Elbows—red
Elbows—rusty
Wrists—size
Wrists—fat
Hands—size
Hands—length
Hands—width
Hands—big joints
Hands—nature and shape
Hands—moist
Hands—prominent veins
Nails—beauty

III. *Legs and Feet*

Legs—size
Legs—length
Legs—shape
Legs—bowlegged
Legs—knock-kneed
Ankles—size
Ankles—beauty
Feet—size
Feet—length
Feet—width
Feet—beauty

IV. *Trunk*

Size
General proportions of trunk
Proportions of bust
Proportions of hips
Proportions of waist
Proportions of shoulders
Width of shoulders
Slope of shoulders

B. Personal Habits

Care of hair and scalp
Hair arranged in becoming fashion
Hair on back of neck
Hair arranged in prevalent style
Hair on back of neck
Use of perfume on hair
Attention given to facial hair—eyebrows, lashes, etc.
Care of nails
Cleanliness of teeth
Care taken to avoid unpleasant breath
Care in coughing, etc.
Care of eyes—dirt, etc.
Becomingness—care of glasses
Care of skin—cosmetics, etc.
General care of body
Appearance of health

C. Expressive Behavior

General physical pose
Erect carriage
Air of dignity
Suggestion of social training
Vivacity, energy
Nervousness
Pleasing manner of walking
Pleasing manner of standing, etc.
Graceful in use of hands
Graceful in use of legs and feet
Tendency to laugh
Tendency to frown
Tendency to smile
Nature of laugh
Tendency to cry
Tendency to pout
Tendency to show teeth
Use of muscles around eyes
Tendency to use facial expression
Attitude towards others—external evidences of interest
Tendency to touch other people
Handshake pleasing
Looks at you straight in eye
Attractive street habits
Attractive table manners
Attractive society manners
Attractive home manners
Tendency to use baby talk.

D. Voice

Modulation
High pitched
Quality, timbre
Intensity
Distinctness of articulation

E. Dress

Good taste in dress: emphasis upon personal taste rather than upon style; pleasing effects
Tendency to follow prevalent styles
General neatness, orderliness, care

2. *The Extent to Which Physical Elements Contribute to the Appeal of Intimate Associates.*—Having secured an inventory of physical characteristics, it was the next concern of the writer to determine their rôle in the selection made by an individual of his intimate friends and associates. It was thought that they could be isolated and measured only by an experimental situation, which would force an individual to rank his intimate associates in the order of his general preferance for them, and then to rank them with reference to a number of abstracted traits, in the hopes that the correlations existing between the order of preference and the various traits would explain the preferences.

This was done with a mixed group of advanced students. It should be noted, of course, that a university student differs in one essential respect from a business or professional man. His associates are not selected primarily on the basis of professional interests. It may be argued, however, that just for this reason the student is the better prepared to analyze the appeal made by his friends. And it is conceivable that the business man temporarily freed from the personal relationships directly due to his vocational environment might show reactions identical with those of the student. But since it was not possible to conduct a control experiment, the following results are offered as characteristic only of the group investigated, with the assumption that they represent a fair sampling of university students.

The members of the experimenting group were asked to write the names of the 10 men and the 10 women for whom they had the greatest degree of personal affection. They were definitely assured that no one would see these names, and they were instructed to represent the individuals listed by the first ten letters of the alphabet. They were then asked, with specific and detailed explanations, to rank these names in their order of personal preference, irrespective of the sex of the individuals listed, and irrespective of extraneous interests of any kind.

They were given no intimation of the nature of the experiment until the lists and rankings had been completed.

They were then given mimeographed forms, provided for the purpose, and instructed to rank the individuals listed with reference to each of a number of characteristics. They were thus forced, by this method, to assign some one in the list to first place, some one to second, etc., as regards each characteristic.

The various rankings were each plotted against the order of personal preference, and the medians drawn. It was thought desirable to establish tendencies, and the relative strength of each tendency, rather than exact correlations. Yule's formula

$$Q = \frac{(AB)(\alpha\beta) - (A\beta)(\alpha\beta)}{(AB)(\alpha\beta) + (A\beta)(\alpha\beta)}$$

seemed sufficient for this purpose, and it was accordingly used. The fact that it disregards differences above and below the median provides against any error due to uncertainty on the part of the judges; for, while they were not always sure of all the relative positions assigned, they were sure that their differences extending over three places were reliable. The following table, then, is submitted as showing only differences in tendencies; and the range of the coefficients seems to indicate actual differences in these tendencies. The various coefficients, each representing a comparison between the order of personal choice and some characteristic or trait, are as follows:

Extent of acquaintance	+.77
Expressive behavior pleasing	+.69
Affectionate disposition	+.69
Individuality of friend	+.66
Sincerity of friend	+.64
Physical attractiveness	+.60
Consistent nature of friend	+.57
Sense of humor	+.57
Accomplishments—social	+.55
Personal habits pleasing	+.55
Physical appeal	+.50
Ethical ideals	+.48
Intelligence	+.48
Voice pleasing	+.38
Vivacity, energy	+.38
Beauty of face	+.37

Optimistic disposition	+.37
Refinement—intellectual	+.37
Beauty—hands and arms, legs and feet	+.22
Dress pleasing	+.13
Beauty of body	+.13

The range of the coefficients does seem to suggest a partial explanation of the basis for personal friendships. Naturally, the friends best liked are the ones best known. And since each judge was instructed to rate on the basis of his own personal reaction, individuality and sincerity are both relatively high. The instructor was warned that the characteristic of sincerity would not necessarily apply to the associates listed with reference to other people. Ethical ideals and intelligence are evidently not considerations of prime importance. A discussion of the results brought out the fact that these presumably higher traits were presupposed only to a certain extent. They were not positive requirements. The fairly low position given to optimism was explained by the fact that intimate friends are likely to be confidential, and correspondingly inclined to talk about their troubles and worries.

As regards the rôle of physical characteristics in the selection of intimate associates, it is evident that static beauty holds a subordinate position, but it is equally obvious that two other groups of physical elements, expressive behavior and affectionate disposition, rank quite high. Expressive behavior was explained and defined in terms of the items given on the rating chart, listed in the preceding section of this paper. These items include many of the elements which ordinarily constitute refinement, and this fact explains the low position given to that trait. Physical appeal was defined somewhat frankly as recognized sex appeal. While some of the judges insisted that it was a factor quite distinct from the appeal made by manifestations of an affectionate disposition, others held that the two appeals represent one and the same thing. It is safe to assume, therefore, that sex appeal should occupy a higher position than the one actually accorded to it. But it was obvious, both in the results of this test and the test reported below, that sex attraction could not be measured by the beauty of the body.

Since the experimenting group consisted of both boys and girls, the experimenter was interested in the possibility of sex differences in the judgments. These differences were not especially in evidence. Of the 21 girls, 13 gave a boy as their choice for first position; of the 8 boys, all gave first place to girls. A further tendency, not at all marked, was discernible for the boys to prefer girls, and for the girls to prefer boys. With the boys, an affectionate disposition was valued when shown by a member of the opposite sex, and sex appeal was predominatly feminine appeal. While the reverse was true, in the main, for the girls, their ratings on the two characteristics made more provision for members of their own sex. No sex differences of any magnitude were to be found in the remaining characteristics.

3. *An Analysis of the Group Characteristics of Physically Attractive and Repulsive People.*—The third investigation was concerned with the physical characteristics of groups distinguished for their positive and for their negative physical appeal. For this purpose, it was thought necessary to study four groups, respectively made up of (1) physically attractive girls, (2) physically attractive boys, (3) physically unattractive girls, (4) physically unattractive boys. The practical difficulties involved in the making up of such lists are obvious. In the case of the first two groups, however, it was decided to face these difficulties squarely.

Seven advanced students, carefully selected by the writer, were asked to write the names of the students on the campus, of both sexes, noted for their extreme physical attractiveness. The names were first written independently, and then compared; and only those candidates who received 5 votes of the 7 were included in the combined lists. The 7 judges then discussed the merits of the candidates, and eliminated a number of them. The writer, of course, had no part in this procedure. Copies of the rating chart were distributed to the judges, with instructions to secure 5 independent ratings on each candidate. Most of the ratings were made by members of the original group of 7; some of them, however, were made by room-mates or fraternity brothers of the

candidates, under the immediate supervision of members of the experimenting group. The writer has every reason to believe that the names listed represented the best possible selection, and that the ratings secured were bona fide.

As it was inadvisable to permit a discussion of physically unattractive people, a different method of securing data for the remaining two groups was followed. A number of judges, selected from advanced courses in psychology, were called together, supplied with the rating charts, and instructed to make individual ratings on people noted for their extreme physical unattractiveness. Each judge was asked to make two ratings, for a boy and for a girl respectively. This method made it impossible to avoid the danger of duplication. Small groups of judges did, however, compare names for the purpose of eliminating the duplicates. As an additional precaution, each of the judges was asked to select people who were probably unknown to the other judges. The method has a further disadvantage, inasmuch as it did not permit the use of more than one rating for each subject; but it is probable that a single rating, by a competent judge, when that rating is made on objective traits, is sufficiently reliable for a study of group traits.

The ratings for the individuals in the first two groups were transferred to a new chart, and the median was taken as the final rating for the individual. The ratings for the individuals in each of the four groups were then copied on a larger chart, and the median judgments on the amount of each trait, and the degree of appeal of each trait, for each group, were ascertained. These results were accepted as indications of group characteristics. All questionable or incomplete records were discarded, and the final groups consisted of 27 physically attractive girls, 14 physically attractive boys, 30 physically unattractive girls, 32 physically unattractive boys.

This particular investigation differs from the usual psychological study of groups in one important respect. Ordinarily, a group is distinguished by some common element, shared by each member of the group. In the present case, however, the common element was an effect produced upon others, and

an effect due to a variety of causes, no one of which was necessarily manifested by any particular member of the group. Any one element, therefore, might presumably stand a chance of appearing in equal amounts in two opposed groups, unless it clearly belonged to only one of them. (In fact, the difficulty of describing group characteristics of this nature is the difficulty which stands in the way of a scientific study of character and personality.) But in spite of this, the results did disclose certain group tendencies. They are summarized in the following statements:

(*a*) Anatomical measurements of the attractive people of both sexes conform to the mode or standard. This means that attractive people were given ratings of 3, 4, or 5, predominatly of 4, on those items referring to anatomical characteristics. Such items were those concerned with the size and proportions of parts of the body, and the amount of hair and fat. The degree of appeal made by these characteristics was also of median intensity. Both statements hold for both sexes.

(*b*) The corresponding anatomical measurements for unattractive individuals show a slight tendency to depart from the mode, and the negative affective reactions to these characteristics show a somewhat greater proportionate tendency to exceed the median. (In other words, any feature, if it conforms to the mode, tends to elicit a favorable reaction of median strength; but if it departs from the mode, it tends to arouse an unfavorable reaction of greater relative strength. These tendencies hold equally well for both sexes.)

(*c*) A few anatomical items disclosed a more definite tendency to depart from the mode, in the case of unattractive individuals. These were found in connection with the proportions and symmetry of parts of the body, and with color. Physically unattractive girls were rated low (in position 2) as regards the color of the mouth and lips, and the proportions of the legs and feet, and hips; physically unattractive boys were rated correspondingly low as regards the proportions of arms and feet. These features, however, were rated only one point above the median (5) in their negative appeal.

(*d*) In terms of the degree of appeal, irrespective of the amount of the trait, the most valuable characteristics shown by attractive girls were clean hair, clean teeth, care taken to avoid unpleasant breath, care in coughing, care of eyes, tendency to arrange hair in prevalent fashion, aristocratic bearing, and general care of the body. These were ranked 6. Two of them, the tendency to avoid unpleasant breath and the care of the body, were also ranked 6 with the attractive boys. The most unpleasant characteristics in unattractive girls were the shape of the chin, proportions of bust, shoulders and hips, the expressions of the eyes and mouth, lack of care of the hair, lack of taste and neatness in dress, absence of aristocratic bearing, poor physical poise. The unpleasant characteristics of physically unattractive boys were quite similar. The eyes, ears, mouth and lips, care of the hands and nails, general care of the body, absence of aristocratic bearing, all came in for unfavorable mention.

(*e*) The results of all the tabulations, including those just referred to, show that physical attractiveness is to be explained primarily in terms of behavior. The items included under the two headings, expressive behavior and personal habits, received more emphasis than the more static items in the list. Beauty is as beauty does. While it is true that a few anatomical items, fairly definitely associated with the sex function, were stressed, these items represented negative, rather than positive, criteria of attractiveness.

A second uniform result is the fact that, in the four sets of measurements, the definite line of separation is to be found between attractive and unattractive individuals. These differ more from each other than the two sexes differ, and the standards of attractiveness are the same for both sexes. This may mean, either that physical appeal is not sex appeal, or that it is sex appeal, with emphasis upon its distinctly homosexual, as well as heterosexual, nature. In the light of the results obtained from the investigation described below, the second interpretation seems to the writer to be somewhat more adequate.

4. *Physical Attractiveness and its Correlated Traits.*—

Physically attractive individuals very naturally elicit fairly constant and uniform responses from other individuals. If we may assume that character is in part a product of social encounter, we may well believe that common traits are to be found in people who stimulate common responses. The psychologist, for instance, who is interested in the question of sex differences, must face the presumption that such differences exist, in spite of the fact that they have been minimized by recent investigations. In these investigations, tests of original nature have been largely employed; but if the conditioned reflex means anything at all, it means that people differ, not so much as regards their instinctive equipments, as they differ regarding the stimuli which bring them forth. So far as social stimuli are concerned, sex distinctions are most certainly made. And distinctions just as great, if not greater, are made between physically attractive and unattractive people. Any study of group differences which stresses innate differences exclusively is necessarily misleading, if it purports to give a picture of actual, existing differences.

In an attempt to secure data upon this question, the writer asked four groups of three judges each to rate a number of their associates, of both sexes, on a number of character traits. All possible care was taken to secure trustworthy results. The median judgment was used as the final rating, and final ratings on 120 undergraduate students, 70 girls and 50 men, were secured. In the treatment of the data, the method of unlike signs again was used. The object was to establish tendencies only, and this method was believed to be sufficient for that purpose.

The traits listed fall into three classifications—namely, general intelligence, attitude towards life, and sex attitudes. The results are as follows:

(*a*) Absence of correlation obtained between general intelligence, as determined by character ratings, and physical attractiveness. The coefficient found was +.02, and the traditional antithesis between beauty and brains thus seems to be without support. In fact, if any a priori case could be made at all, it would favor a positive rather than a negative

relationship. Physical attractiveness presupposes a certain amount of good health, and health, in turn, is certainly not antagonistic to mental vigor. Again, physically attractive people are in demand; they are more likely to mingle with people than are unattractive individuals, and as a consequence, to acquire the wisdom which results from such intermingling. While no correlation was attempted between university grades and physical attractiveness, the presumption, again, would be in favor of a slight positive relationship in the group investigated; for the scholastic requirements at the University of Texas are higher for fraternity than for non-fraternity students. Needless to say, the attractive people were recruited predominantly from the fraternity groups. To offset these influences, the fact remains that the attractive student in a coeducational institution is not forced to rely upon mental ability alone, either for academic or for social success. The coefficient found, therefore, probably represents approximately a true relationship.

(*b*) If it is true that a social premium is placed upon physical appeal, it would follow that individuals so endowed tend to live a more active social life than individuals less in demand. As the result of this greater emphasis upon social activity, we should expect to find a greater practical knowledge of human nature. And we should expect, too, that this knowledge would be concerned with sex attitudes. With this possibility in mind, the writer described three general attitudes, and asked for ratings on these attitudes. The three were included in a total list of 33, and the judges had no intimation of the immediate use to be made of the data. An idealistic attitude was defined in terms of conscious emphasis upon ideals—religious, social, ethical, or æsthetic; a sophisticated attitude was explained as a practical knowledge of human nature, particularly as it is manifested in sex relationships, with a reliance upon that knowledge, rather than upon some ideal, as a basis for conduct; and a blasé attitude was described as a sophisticated point of view, plus an acceptance of human nature as it is found, with no tendency to be shocked at some of its weaknesses.

These character estimates were each correlated with a

trait described as "Liking for Opposite Sex." This trait was defined from a behavioristic standpoint. It presupposed, therefore, not only a passive liking for the opposite sex, but an active tendency to manifest this disposition.

The coefficient found between the ratings for this trait and the ratings for idealism was −.31, while sophistication yielded a coefficient of +.41. and blasé attitude, +.13. The distribution was approximately the same, on each of the scatter diagrams, for the two sexes. Comment is perhaps superfluous, but it may be stated that the results are about what one should expect.

(*c*) A number of traits were described, all concerned more or less directly with physical attractiveness and sex attitude. The relationships among these traits, as established by the *Q* formula, are as follows:

General physical attractiveness and appeal to opposite sex	+.87
General physical attractiveness and appeal to same sex	+.52
Appeal to opposite sex and appeal to same sex	+.41
Liking for opposite sex and liking for same sex	+.35
Appeal to opposite sex and liking for opposite sex	+.58
Energy, vivacity, and appeal to opposite sex	+.44
Energy, vivacity, and appeal to same sex	+.38
General social ability and physical attractiveness	+.71
Good taste in dress and physical attractiveness	+.83

It is evident that traits closely associated with positive sex appeal tend to show positive correlations. It is also obvious that our results do not indicate the presence of a line of demarcation between sex appeal and physical attractiveness. Which is the larger and more fundamental term of the two is a matter of conjecture, or possibly, of definition; but, all results considered, one may entertain the hypothesis that the traits listed represent a linear series of responses, with overt sex desire at the maximum end of the series. Sex appeal exists, and since it can not be readily isolated from other appeals, we can only assume that it operates through them, and that it is to be identified with them. If fondling and physical contact—those aspects of behavior which constitute an affectionate disposition—are sexual in nature, we may find added support for this interpretation in the high place given to that trait in the investigation described above.

APPARATUS FOR THE STUDY OF VISUAL AFTER-IMAGES

DONALD A. LAIRD

University of Iowa

As a rule the experiments with positive visual after-images are among the least successful of the experiments in the introductory laboratory work in psychology. The simple and easily constructed arrangement to be described has been found to be very effective in demonstrating, under a variety of conditions, this phenomenon which is usually rather elusive to the beginning student. Some research value attaches to the apparatus due to the simultaneous arousal of both the positive and negative after-images under comparative conditions and the observations on the course of retinal adaptation or fatigue which can be approached by way of after-images with the device to be described. The simultaneous appearance of the two images favors the identification of the positive and negative by the uninitiated. The sequence of temporal changes in the images is especially striking and pertinent to the functioning of the retina. The beauty and uniqueness of the phenomena elicted with this arrangement insures an active interest on the part of the observers.

The apparatus consists essentially of a reflecting surface adapted so that it can be readily covered with colored linings and a concentrated filament electric bulb placed so that an intense and approximately even illumination is given the linings. The details given here are for an arrangement illluminated by a 50 watt type C Mazda bulb. If it is desired to use a larger source of illumination it will be necessary to modify all the specifications given so that the reflecting linings are evenly lighted.

The general lay out will be plain from an examination of Figure 1 which shows a cross section through the centre of the

apparatus. A mounting board (MB) about 26 cm. square is fitted with a screw eye (S) along the middle of one edge that the complete arrangement may be hung on the wall at a convenient height. A porcelain base socket (PS) is

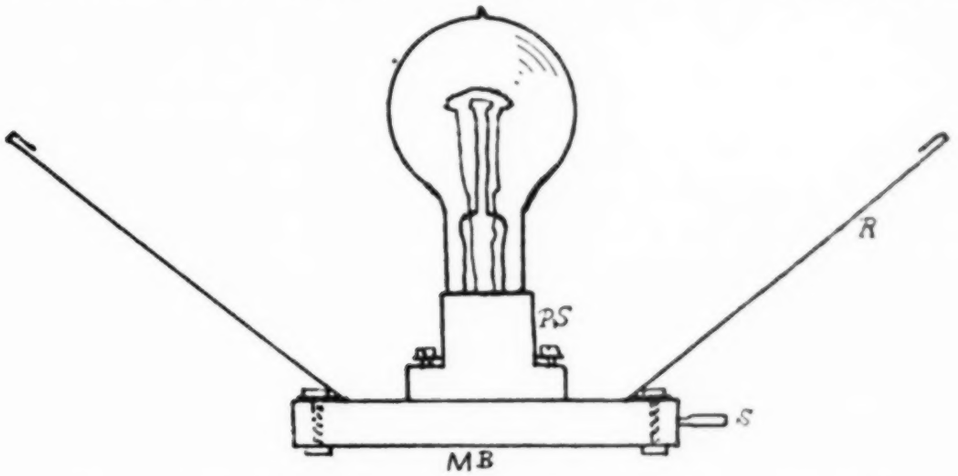


FIG. 1. Semi-diagrammatic cross section through middle of apparatus.

fastened at the centre of one surface of the mounting board and the reflecting surface (R) is mounted so that it is centered around the lamp. Working plans of the reflecting surface are given in Figure 2. This is preferably made of tin and then blackened after assembly. The outer or larger edge of the reflector is turned in to retain the sectors of colored papers which are used to line it and which serve as the stimuli for the larger field of after-images. The radii given are indicated in centimeters. As indicated in drawing 2 a sector of 75° is cut away from the reflector pattern to give the most advantageous angle to the completed surface. The four ears left on the 6 cm. circle are used to fasten the reflector to the mounting board. Care must be exercised in selecting the material out of which the reflecting surface is formed for if it is of a very heavy guage it cannot be formed into the conic frustrum after the retaining groove has been made without rendering the groove useless from "buckling." The dimensions given in Figure 2 may also be used in cutting the colored linings.

Observations may be made in a fully lighted room but the plainest images are obtained in a light proof room after

dark adaptation has been accomplished. Here, as in other related observations, a stimulation of a duration so short as to preclude eye movements is desirable and for a simple

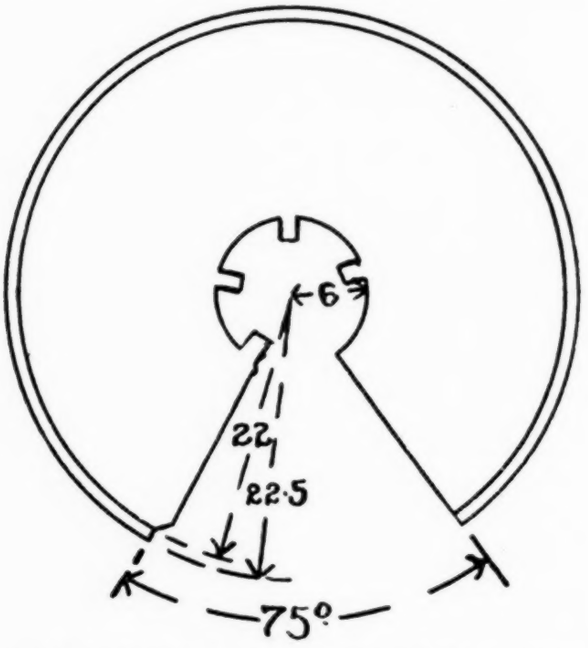


FIG. 2. Working drawing for construction of the reflecting surface.

study of after-images only monocular observation is to be preferred. A group of ten to fifteen can make observations varied and sufficient for class demonstrations or exercises. The most satisfactory and illuminating observations, however, are possible only when the reflecting lining practically covers the entire monocular visual field.

This apparatus gives rise to an almost unparralled series of images. The U-shaped filament of the bulb gives rise to the *first* positive image while the linings give predominantly negative images. Due to the spread of the linings over the entire visual field and the retinal zones a significant series of qualitative changes and temporal as well as spatial differences can be noted even by an inexperienced observer. If it is desired the image of the filament may be practically eliminated by using a type C-4 Mazda in which the bulb is white coated—not frosted.

While this device is especially useful in group demonstrations in introductory courses it also can be put to a very

serviceable use in the more advanced and exclusivelly laboratory courses. At the present it is being used for a study of the course of retinal adaptation by means of after-images but its value as a didactic device prompts placing it at the disposal of psychologists in general.

THE MODIFICATION OF THE INTENSITY OF SENSATION BY ATTENTION

BY S. M. NEWHALL

Wesleyan University

I. INTRODUCTION

The general problem of the present report may be stated as follows: what change, if any, in the intensity of sensation is caused by change in attention? The historical part aims to very briefly summarize the available facts and theory of the whole field of the effect of attention on the intensity of sensation. The experimental part has aimed to deal with what may be termed direct effects of attention on sensational intensity. To this end it has seemed possible to factor the attention problem by abstracting from certain of the effects of attention which are physiologically conditioned, such as; the increase in the intensity of sensation which is a usual concomitant of sensory accommodation, and the decrease in intensity which results from sense-organ fatigue. Sensation-changes caused by sense-organ changes, when the latter follow from the functioning of the sense-organ in the attentive process, cannot be said to be due directly to attention.

The experiments were confined to a single sense-field, namely, audition. This is largely accidental and should be regarded as the beginning of a more general experimental attack. The reason why we began the investigation with sound was because binaural hearing seemed to offer exceptionally satisfactory conditions for attention-changes with a minimum of adjustment of the sense-organs, while changes in the position of the binaural phantom seemed to offer unusually clear and unambiguous criteria for changes of relative intensity.

The general problem is of considerable interest and importance. We are still profoundly ignorant of the nervous correlate of attention. Whether it is conditioned by the fundamental neural processes of summation and refractory phase, reinforcement and inhibition, or whether it is ex-

clusively an affair of apperceptive integration we are totally in the dark. The question whether attention conditions any real modification of intensity, and the quantitative question of degree of intensive change, has far-reaching implications in dynamic psychology.[1]

Our immediate experimental problem may be stated as follows: what sort of an effect, if any, do greater or lesser degrees of attention have upon the intensity of an auditory sensation, when the latter corresponds to a stimulus of standard effectiveness as far as the sense-organ is concerned.

II. HISTORY

An historical summary of our problem readily divides into two parts, namely: (*A*) a descriptive account including what have appeared to be significant observed facts, and (*B*) a review of attentional theories which take account of the question of intensive change as due to attention.

A. On the phenomenological side we find a great variety of observation and opinion; and we make a four part division according as the attention has apparently (1) constituted an existential condition for sensation, (2) effected no change, (3) an increase, or (4) a decrease in sensational intensity. These categories seem to include all the possibilities if we let them cover both relative and absolute changes.

1. The evidence from a mass of more or less desultory observation and experiment seems to indicate that some degree of attention is necessary for sensational consciousness. Our experiments tend to prove this. While hundreds of examples of what is meant may be drawn from popular experience; the fact, as it seems to us, has been scientifically described by Fechner,[2] Ulrici,[3] G. E. Müller,[4] and A. Dissard.[5]

[1] Both for the problem and for the general experimental method, I am indebted to Professor Raymond Dodge. I take great pleasure in expressing my thanks for his frequent aid and advice.

[2] 'Elemente der Psychophysik,' Leipzig, 1860, II, 452–3. 'Revision der Hauptpunkte der Psychophysik,' Leipzig, 1882, 270–2.

[3] Cited by Geyser, Joseph: 'Ueber den Einfluss der Aufmerksamkeit auf die Intensität der Empfindung,' Munich, 1897, 14–17.

[4] Cited by Geyser: *Op. cit.*, 17–18.

[5] 'Influence de l'attention sur la perception des sensations,' *Revue Philosophique* XXXIX., 1895, 454–5.

2. The evidence in support of the hypothesis of no change in intensity is relatively insignificant. Fechner,[1] Ulrici,[2] Lipps,[3] and Geyser[4] each concluded that attention has no effect on sensory intensity. Wundt[5] believed that any intensive effect was quite unessential and secondary. Külpe's[6] later experimental results point in the same direction. C. S. Meyers[7] and Felix Arnold[8] are quite undecided concerning the general question as to whether or not there is any intensive change directly attributable to attention.

3. Introspective evidence for an increase in intensity is so varied as to make detailed classification impracticable. A considerable group of writers, however, find a limited increase. G. E. Müller[9] notes intensification of weak sensations and in exceptional cases; while Stumpf[10] finds such intensification to be the rule in audition. Wundt,[11] Nicolai Lange,[12] James,[13] Stout,[14] and Ward[15] also favor a certain limited intensive increase with attention.

There is, further, a group who are inclined to believe that there is some considerable increase in sensory intensity due to attention. Hibben[16] draws a general conclusion of intensive increase from the study of a pathological child. Exner[17] maintains that attention directly increases sensational

[1] 'Elemente d. Psychophysik,' II., 452–3. Revision, 270–2. In 'Sachen der Psychophysik,' Leipzig, 1877, 86.

[2] *Loc. cit.*

[3] 'Grundthatsachen des Seelenlebens,' Bonn, 1883, 134–5. Geyser, *op. cit.*, 25–6.

[4] *Op. cit.*, 57, 103.

[5] 'Grundzüge der Physiologischen Psychologie,' 6 Aufl., III., 315.

[6] 'Der Einfluss der Aufmerksamkeit auf die Empfindungsintensität. Dritter Internationaler Congress f. Psychologie,' Munich, 1897, 180–2.

[7] 'Experimental Psychology,' London, 1909, 319.

[8] 'Attention and Interest,' New York, 1910, 27–8.

[9] Cited by Geyser, *op. cit.*, 18.

[10] 'Tonpyschologie,' Leipzig, 1883, I, 373–5. *Op. cit.*, 1890, II, 290–2, 293–4.

[11] *Op. cit.*, 4 Aufl., II., 274. *Op. cit.*, 6 Aufl., III., 314–5.

[12] 'Beiträge zur Theorie der sinnlichen Aufmerksamkeit,' in Wundt's *Philos. Stud.*, Leipzig, 1888, IV., 391, 421.

[13] 'Principles of Psychology,' New York, 1896, I., 425–6.

[14] 'Analytic Psychology,' New York, 1909, I., 250–1.

[15] 'Psychological Principles,' New York, 1919, 69, 119.

[16] 'Sensory Stimulation by Attention,' *Psychological Review*, II., 372.

[17] 'Entwurf zu einer physiologischen Erklärung der psychischen Erscheinungen,' 1894. Especially 163–171.

intensity, but that this increase by attention is recognizably different from increase due to increase in intensity of stimulation. Ebbinghaus[1] says, "A general increase of the intensity of sensation through attention is . . . thoroughly probable." Titchener[2] favors this view also. While Pillsbury[3] gives the problem considerable attention and states that it is quite unsettled, he seems to favor the positive view.[4] Mach,[5] over thirty years ago, and Bentley[6] about fifteen, came to the experimental conclusion that attention intensifies moderately intense auditory sensation. Bentley, indeed, found the intensification to be relative to the absolute intensity of stimulation,[7] confirming the speculation of Pillsbury.[8]

4. The experimental findings of two psychologists seem to fall in the paradoxical category. While extensive criticism[9] has shown Münsterberg's results[10] to be invalid as far as general significance is concerned; they appear to correctly indicate the decrease in intensity which is often experienced under expectant attention. Tsukahara's results,[11] as interpreted by himself, are opposed to those of Münsterberg; but, as it seems to us, the more correct interpretation indicates a decrease in intensity with attention. Tsukahara's experimentation is open to grave criticism, and therefore must not be taken too seriously.

The available evidence from the data of consciousness is very diverse. While the weight of opinion favors some interdependence of clearness and intensity, the problem cannot be said to be settled.

[1] 'Grundzüge der Psychologie,' I., 586, 588.

[2] 'A Textbook of Psychology,' New York, 1919, 279–280. 'Lectures on the Elementary Psychology of Feeling and Attention,' New York, 1908, 212–220.

[3] 'Attention,' New York, 1908, 2–11.

[4] Titchener, Lectures, 212.

[5] 'Tonpsychologie,' II., 293–4.

[6] Titchener, Lectures, 361–6. Briefly reported in *Psychological Bulletin*, IV., 1907, 212 f.

[7] Titchener, Lectures, 363–4.

[8] *Op. cit.*, 3.

[9] *E.g.*, by Stanley, H. M., 'Attention as Intensifying Sensation,' *Psychological Review*, II., 1895, 55–7. Hamlin, *op. cit.*, 43–66.

[10] 'The Intensifying Effect of Attention,' *Psychological Review*, 1894, I., 39–44.

[11] 'Problem of the Relation of Intensity of Sensation to Attention,' Hiroshima, Japan, 1907.

B. On the theoretical side we also find a variety of views, but the problem of classification is less difficult partly because we shall consider here only attentional theories which have seemed significant in relation to our problem. There are six types of theory to be noted, each one of which makes some attentional factor or aspect (as Pillsbury would say) the causal principle. These explanatory principles may be stated as follows: (1) centrifugal reinforcement of sensory impulses, (2) central psychical reinforcement, (3) prominence in consciousness due to inhibition, (4) prominence due to combined facilitation and inhibition, (5) attention as essentially conditioned by motor factors, and (6) the identity of clearness and consciousness.

1. In attention, centrally originated centrifugal impulses in the afferent pathways summate with the centripetal impulses underlying the sensation, with consequent intensification of the latter. According to Stumpf,[1] this summation process is a common accompaniment of the attentional intensification of weak sensation, and of the raising of subthreshold stimulation to consciousness. In its essentials this theory was also held by G. H. Meyer[2] and G. E. Müller.[3]

2. The reinforcement in this type of theory is purely psychical. The reinforcement may be by congruent memory images, kinæsthesis or other contents of consciousness (Lotze,[4] Wundt,[5] Ulrici[6]); or it may be due to the 'Energie' of the mind itself as a whole (Lipps[7]). The conscious result is in general increased clearness and distinctness.

3. The inhibition theory—both physiological and psychological—increases the prominence of a content by the reduction of the rest of the field. This is the theory of Wundt,[8] Nic. Lange,[9] and Külpe.[10] It involves primarily changes in

[1] *Op. cit.*, I., 374–5.

[2] 'Untersuchungen über die Physiologie der Nervenfaser,' Tübingen, 1843, 250.

[3] From a quotation by Geyser, *op. cit.*, 17–18.

[4] 'Medizinische Psychologie,' Leipzig, 1852, 509. 'Microcosmos,' Leipzig, 1856 (tr. N. Y., 1897), 209.

[5] *Op. cit.*, 4 Aufl., II., 274. 'Outlines of Psychology,' 3d ed., Leipzig, 1907, 238.

[6] Cited by Geyser, *op. cit.*, 15.

[7] *Loc. cit.*

[8] *Op. cit.*, 4 Aufl., II., 274.

[9] *Op. cit.*, 421.

[10] 'Outlines of Psychology' (tr.), 1895, 445.

relative clearness and only concerns intensive modification in an incidental way.

4. Exner[1] combines the theories of facilitation and inhibition and makes the former the more fundamental in attention. This compound theory has a detailed physiological grounding; and its exponent states that attention directly increases sensational intensity. He notes, as stated above, that attentional increase is different from stimulational increase.

5. Ribot[2] is the important exponent of motor theory, and he makes movement the cause and the phenomenon of attention. This theory is open to serious criticism as is also the motor theory of Münsterberg;[3] which is similar to Ribot's though much less thoroughgoing. Motor theory forms the basis for the statement that strain sensations arising in the attention process may be the cause of over- and underestimation of the stimulus attended to.

6. As noted in our descriptive account (*A*), there is a very close relationship between consciousness and attention. Kohn[4] identifies the two. While some degree of attention is always involved in consciousness, fusion of the two concepts would be unfortunate in many respects. Feeling has no clearness.

III. EXPERIMENT

An Investigation of the Effect of Attention on Sound-Intensity

A. A Secondary Objectified Criterion of Change in Tonal Intensity

Our experiments are concerned with the effect of attention on the intensity of noise. The following indirect method was used because it seemed easier and surer than the alternative method of direct comparisons. The observer is presented with a binaural sound and makes a judgment as to change in the location of the phantom when the attention is directed to

[1] *Op. cit.*

[2] 'The Psychology of Attention' (tr.), 3d ed., 1896.

[3] *Op. cit.*

[4] 'Zur Theorie der Aufmerksamkeit,' Halle, 1895. Cited by Pillsbury, *op. cit.*; 292 f.

one component; as compared with its location when the attention is not given a particular direction, or when it is directed to the opposite component.

We provisionally assume that if the phantom shifts with the attention, while the stimuli are in the same phase, of equal frequency, and constant intensity, there is a change in the relative intensity of sensation. This assumption is based on the fact that, aside from asymmetrical auditory fatigue or systemic rhythms, if wave-phase and frequency are constant, the only remaining known determinant of the position of the phantom is the relative intensities of the binaural stimuli.

B. Apparatus

The experiments fall into two main groups differentiated by the procedures followed. The set-up of apparatus is essentially the same in both groups, and it was distributed among three adjacent rooms to be known respectively as *A*, *B*, and *C*. We may perhaps most clearly describe the set-up by tracing the path of the energy-changes which finally produce the auditory stimuli for the observer.[1] These start with a tuning fork and end with telephonic diaphragms. The set-up is diagrammatically represented in Fig. 1.

In room *A* there was an electromagnetically driven Koenig fork (*f*) of 100 V.D. The source of current was three chloride accumulators (*ch*). A D.C. milliammeter (*mi*) and a variable resistance (*r*) made it possible to adjust the intensity of the current. The leads from this circuit passed into room *B*.

In room *B* the leads were attached to the primary (*i*1) terminals of an inductorium situated on the experimenter's[2] table. There were two shunts across the primary terminals, (*a*) a variable resistance and (*b*) a mercury-contact short-circuiting key. The latter normally remained closed, and it was important that its operation cause no disturbing clicks in the receivers of *O*. Across the terminals of the secondary (*i*2) was connected the resistance wire (*w*) of a wheatstone bridge. The sliding contact (*s*) used on the bridge-wire was weighted to maintain an even pressure.

[1] 'Observer' is hereafter designated by *O*.

[2] 'Experimenter' is hereafter designated by *E*.

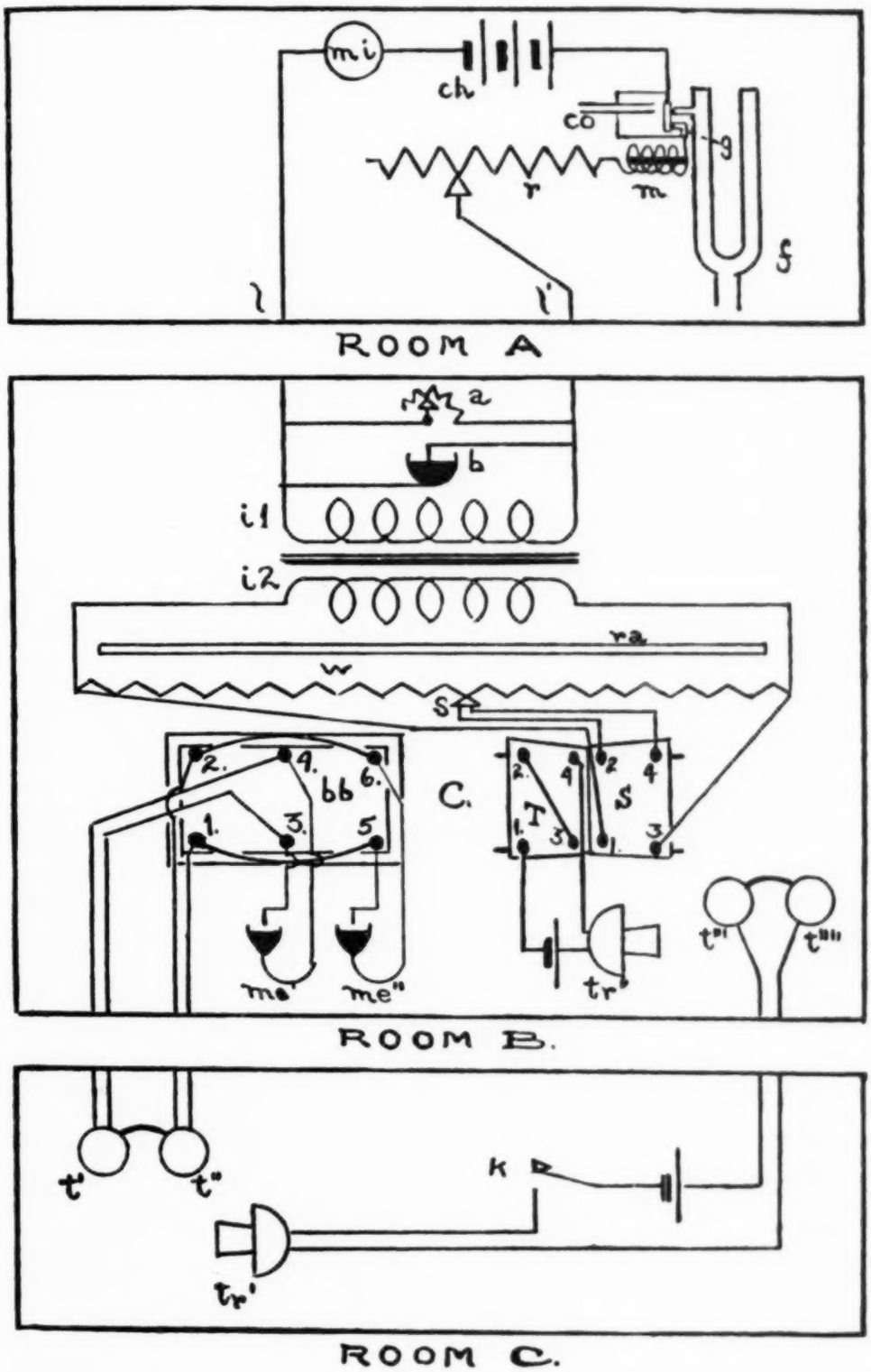

mi
ch
co
g
r
m
S
l
l'
ROOM A
a
b
i1
i2
ra
w
S
2.
4.
6.
bb
1.
3.
5.
C.
T
S
me'
me"
tr'
t'''
t''''
ROOM B.
t'
t"
K
tr'
ROOM C.

FIG. 1.

Two flexible wires from the sliding contact and one from either end of the bridge-wire led into a mercury pole-changer (*c*). They were there so connected with a four-wire line leading to *O*'s receivers in room *C* that one receiver was connected across the sliding contact and one end of the bridge-wire while the other receiver was connected across the contact and the other end of the bridge-wire. When switch (*b*) was open, the relative resistances of the receiver circuits could be varied with the sliding contact. It was thus possible to vary the relative amounts of current in the receiver-coils and so the intensity of the auditory stimuli; while the total intensity remained approximately unchanged. Mercury contact shortcircuiting keys (*me'*, *me''*) made it possible to cut out either of *O*'s receivers.

The time relations of the stimuli were determined within the personal equation of *E* by operating the shortcircuiting key (*b*) synchronously with the swinging of a seconds pendulum in *E*'s visual field.

The experimenter was provided with a wireless headset (*t'''*, *t''''*) for receiving introspection from *O*, and a mounted telephone transmitter (*tr''*) for talking to *O*. By manipulation of the mercury pole-changer (*c*), *E* could instantly disconnect *O*'s headset (*t'*, *t''*) from the bridge-wire and connect it with his transmitter (*tr''*). This change in connection was accomplished by the use of an eight point contact block. Four of the contacts (*S* 1234) when inserted in mercury pools of the base block (*bb*) serve to connect *O*'s headset with the bridge. This is the connection for stimulation. The other four contacts (*T* 1234) when they are inserted in the base block pools, connect *O*'s headset with *E*'s transmitter. This is the connection for instructions. In regard to the bridge-wire, the connections of *O*'s receivers are interchanged when *S* 1234 are inserted in the four base block pools to the right hand (*bb* 3456), as compared to insertion in the four left hand pools (*bb* 1234).

Six wires pass from room *B* to room *C*, two of which lead to each of *O*'s receivers and two to his transmitter (*tr'*). Considerable care was taken to make the contacts as good as

possible in *O*'s receiver circuits. Wherever practicable contacts were soldered or were mercury pools. Since *O*'s transmitter and *E*'s headset were in a separate circuit, *O* could speak to *E* whenever desirable. The observer was seated alone in room *C* which is windowless, and the least noisy room in the laboratory. The transmitter was mounted on a level with his mouth and he closed the telephonic circuit when talking by means of thumb and finger compression on a telegraphic key (*k*). On the white wall opposite *O*, and about three meters away was a plainly marked fixation point.

C. Procedure and Results

Group I

Procedure.—*E* presents *O* with a plainly audible binaural sound of standard intensity. *O* telephones the apparent location of the phantom to *E*. *E* varies the relative intensities of the left and right components and then gives a second stimulation. *O* telephones the new localization judgment. By continuing this process for one minute or less, *E* determines the position of the sliding contact which corresponds to localization of the phantom in the approximate median plane. From this contact position and two positions at 5 cm. intervals on either side of it, *E* constructs a table on his record sheet. For example, if 45 cm. is the median contact position then the other contact positions will be 35, 40, 50, and 55 cm. The five positions determined in this manner were the 'stimulation points' for a complete experimental series or single sitting of *O*.

A series consists of either three or four parts with 25 'record' stimulations in each part. Five record stimulations are given at each of the five contact settings, following a predetermined chance order. The first part is a 'normal' part, *i.e.*, 25 stimuli of a full second's duration and 4 seconds interval are presented in the chance order. This is with visual fixation in the median plane and no other specific direction of the attention.

In the second part, *E* presents *O* with a 1 second left (or right) preliminary stimulus. The preliminary stimulus is

followed by the binaural stimulations in chance order as above. *O* is instructed to direct his attention to the preliminary stimulus, and to maintain his attention-set until after the reception of the binaural or record stimulus, the localization of which he judges and immediately phones to *E*. *E* follows the chance order of stimulation and part two of the series is completed.

The interval between the preliminary stimulus and the record stimulus was in 18 parts 2 seconds, in 28 parts 1 second, and in 11 parts 4 seconds. There was thus a total of 1,425 experimental judgments in Group I.

Seventeen of the series were completed with a third part which was normal, *i.e.*, the same as part one; while 20 others contained a second experimental part with a time interval shorter, equal or longer than in the first experimental part. Every series began and closed with a normal part.

In a few series the intensity of the experimental stimulus was increased and in a few decreased. In a few series the *O*'s eyes were allowed to move 'naturally' to the side to which attention was given. The results from these series are insufficient for tabulation but are later discussed.

Seven observers served in the experiments of Group I., *i.e.*, D., N., Di., F., H., S., and W. Introspection was encouraged and with the exception of D. and N. they worked without knowledge. With the above exception, they were all Wesleyan undergraduates taking or having taken two or more psychological courses. Each served for not more than one hour on a given day. Their generous disposition of time and careful work is greatly appreciated.

D. served in 4 series and made 100 record judgments, while N. served in 5 series and made 150 record judgments. Di. and S. each served in 5 series and made respectively 200 and 225 record judgments. F., H., and W. each served in 6 series and made 250 record judgments each. Thus there was a total of 37 series and, as noted above, 1,425 experimental judgments. Since the first and last part of each series was normal, there were 50 normal judgments in each series or a total of 1,850 normal judgments.

TABLE I

EXCESS JUDGMENTS TO THE SIDE OF THE ATTENTION AND THE UNIAURAL PRELIMINARY STIMULUS

Observer	Conditions of Stimulation												Totals		
	L1		R1		L1, L4		R1, R4		L2, L2		R2, R2				
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	% Minus Excess
D.....	0	11	1	19.5									1	30.5	97
N.....	0	16	6.5	4.5	0	12							6.5	32.5	83
Di.....	0	17	1.5	0	0	51	0	22	0	14.5	(*a*)		1.5	104.5	99
F.....	0	7	8.5	0	4	6	4	6	3.5	2.5	1	4	21.0	25.5	55
H.....	0	4.5	0	12	0	20.5	0	24	0	23	0	15	0	99.0	99
S.....	(*b*)		0	5	0	16	0	13	0	22	0	16	0	72.0	72
(*c*) W.....	0.5	0	10	0	33	0	0	52	2	4	22	0	67.5	56.0	45
Sum of totals													97.5	420.0	81%

Table I shows the bias of judgment of position caused by an uniaural preliminary stimulus.

Columns L1 and R1 include the results when the binaural stimulus followed the uniaural Left or Right preliminary stimulus after an interval of 1 second. L2, R2, L4, R4, have analogous meanings.

The plus (+) column gives the excess of judgments in the direction of the uniaural preliminary stimulus. The minus (−) column gives the excess of judgments in the opposite direction. Each figure gives the total excess, plus or minus, judgments resulting from all experiments on any observer under the conditions indicated.

(*a*) Thrown out on introspection which clearly indicated inadequate stimulation.

(*b*) Thrown out on an introspective report of 'tendency to eye-movement' to the side of preliminary stimulus.

(*c*) This *O* is subject to catarrhal trouble. He is the only *O* who made more judgments to the side of the preliminary stimulus than to the opposite side.

The total number of record judgments from which the excess judgments were computed is 1,500 minus the 75 rejected as explained in footnotes, or 1,425 judgments.

Seven per cent. was the excess of the total record judgments to the side of the preliminary stimulus (+), and 30 per cent. was the excess to the opposite side (−). The preponderance of "minus" over "plus" excess judgments is 30.0 divided by (30.0 plus 7.0), or 81 per cent. as shown in Table I.

While the number of excess judgments is, in each case, a small per cent. of the total record judgments, it is significant, with the exception of two cases, that there is a far greater per cent. of excess judgments to the side opposite to that of the preliminary stimulus, than there is to the side of the preliminary stimulus. This relation is strikingly shown in the last column of Table I., where, using in each case the total excess judgments as a basis, the per cent. of judgments to the side opposite to the preliminary stimulus is given.

Results.—The numerical results of Group I. were computed, for each series, in the following way: In part one of a given series, the number of left, center and right judgments were respectively counted. The judgments for the other normal part were counted in the same way. The 'center' judgments of each part were evenly split into the left and right judgments of such part. The average of the left judgments (including one half the center judgments) was then determined; and likewise with the right judgments. The experimental parts were treated in the same way. The sum of the differences of the experimental and normal judgments was then determined. The resulting figures indicate the 'excess' left or right judgments for the experimental parts as compared with the normal parts.

TABLE II

EFFECT OF INCREASING THE INTERVAL BETWEEN THE PRELIMINARY STIMULUS AND THE RECORD STIMULUS

Observer	Conditions of Stimulation							
	(L_1, R_1, L_4) (R_4)				(L_2, R_2, L_2) (R_2)			
	+	−	+	−	+	−	+	−
Di.....	0	44	0	29	(*a*)		(*a*)	
F.....	4	6	4	6	3.5	4	1	2.5
H.....	0	25	0	19.5	0	18.5	0	19.5
S.....	0	18	0	11	0	15.5	0	22.5
Totals.....	4	93	4	65.5	3.5	38.0	1	44.5
Ex Di.....	4	49	4	36.5				

The differences between 1 second and 4 second intervals as shown in Table II. indicate that there is a decrease in the number of excess judgments to the side opposite to that of the preliminary stimulus when the inter timulation interval is increased. In the left half of the table the excess judgments following the 4 second interval are in each case, save one, fewer than the excess judgments following the 1 second interval. The results in the right half of the table seem to show that this result is not due to temporal order. For in the right half of the table the interstimulation periods are both 2 seconds and there are a slightly *greater* number of excess judgments on the second record stimulus, whereas in the left of the table there are *less* excess judgments on the second record stimulus.

(*a*) Thrown out because the introspective report indicated that the stimulation was inadequate in series "R_2, R_2." The total used number of record judgments is consequently 700.

Group II

Procedure.—Effort to eliminate the complicating asymmetrical fatigue effect due to the uniaural stimulus employed in Group I., led to a second group of experiments with the following procedure. Each *O* was given preliminary training in 'hearing-out' the left and right components with the phantom sound in the median plane. This type of hearing-out consists in a voluntary arbitrary emphasis on the given component, with resulting localization of the sound to the corresponding side. The experience of hearing-out is clean-cut and definite. The *O* is quite confident of the fact when he has heard out a given component. The fact of hearing-out seems to indicate a high degree of attention.

In order to eliminate the possible effect of gross eye-movement, the hearing-out in over one half of the experiments of Group II. was done with visual fixation in the median plane. All of the *O*'s found it possible to separate eye-movement and direction of attention.

As in Group I, interstimulation intervals of 1, 2, and 4 seconds were used. Also stimulation at three different intensities was tried, *i.e.*, slightly suprathreshold, plainly audible as in Group I., and moderately intense stimulation. The estimated total amplitudes of diaphragmic vibration are, respectively, 1.52×10^{-7}, 3.12×10^{-7}, and 4.18×10^{-6} cm.[1]

Aside from the above, the procedure throughout was as follows: In any given experimental series, *E* first determines the empirical center and records the five stimulation points as in Group I. Then *O* tries to hear-out of the sound given at the empirical center, the desired component. *O* makes this attempt during a binaural preliminary stimulus of 5 seconds duration. In case *O* does not hear-out in that period, stimulation is discontinued for 5 seconds and then resumed,

[1] These estimates were made from photographing the diaphragmic vibration as communicated to a single taut silk fiber by means of a fine glass rod mounted vertically at the center of the diaphragm. Using the Dodge microscope recorder the shadow of the magnified thread was photographed on moving sensitized paper, and measurement made of the vibrational amplitude in the photograph. The resulting figure was divided by the optical magnification, and corrected for the current flowing in the magnet-coils as compared with the flows under experimental conditions.

and so on, until such time as he does hear-out. It took a practiced *O* not more than one or two 5 second periods in which to hear-out according to instructions. When *O* has heard-out the desired component he gives a double key-click, audible to *E*. *E* then, after a predetermined interval, presents *O* with a record stimulus of a full second's duration, following the chance order for Group II. *O* is instructed to maintain his attention-set throughout the interstimulation interval and until he has judged the record stimulus. After 25 record stimuli have been given the above procedure is repeated while *O* hears-out the other component. Each series, then, consists of two parts.

Six *O*'s served in the experiments of Group II., *i.e.*, D., N., Di., F., H., and S. D. and N. only served in a few series, and while the results were in the same direction as of the other *O*'s, the number of series was deemed insufficient to warrant tabulation of results. Di., F., H., and S. each served in 13 series and made 650 judgments each.

Results.—The influence of attention to the left and to the right on the relative number of left and right judgments is estimated by Yule's coefficient of association.[1] This is computed as follows: In any given series, the total number of left judgments with attention to the left, and the total number of right judgments with attention to the left are counted. In each part of the series the 'center' judgments are evenly split into the left and right judgments. Then the difference of the products of the judgments which are on the same side as the attention and those which are on the opposite to the attention, are divided by the sum of such products. The result is the coefficient of association (Q).

Since the coefficient is computed for the judgments with the attention to both the left and the right together, it represents the total deviation resultant from attention; and not the bias resulting from attention to the left or right component alone. Under the experimental conditions, we cannot properly separate the left and the right biases; and so compute the coefficients for each separately. It is to be noted that the

[1] 'An Introduction to the Theory of Statistics,' London, 1911, 37–8.

TABLE III

JUDGMENTS CONSEQUENT TO HEARING-OUT ONE COMPONENT OF A BINAURAL TONE

A. Eye-Movement to the Same Side

	Observer Di.					Observer F.				
Heard out—	Left		Right			Left		Right		
Interval	+	−	+	−	*Q*	+	−	+	−	*Q*
1″.....	15.5(*a*)	9.5	16.0	9.0	.49	19.5	5.5	21.0	4.0	.90
1″.....	14.5	10.5	17.5	7.5	.53	22.0	3.0	23.0	2.0	.98
4″.....	16.0	9.0	14.0	11.0	.39	17.0	8.0	17.5	7.5	.66
4″.....	15.0	10.0	12.0	13.0	.13	13.0	12.0	22.5	2.5	.84
2″.....	13.0	12.0	19.0	6.0	.55	18.5	6.5	16.5	8.5	.69
2″.....	11.0	14.0	19.0	6.0	.46	14.0	11.0	16.5	8.5	.42
Totals.....	85.0	65.0	97.5	52.5	.42	104.0	46.0	117.0	33.0	.78

B. Central Visual Fixation

	Observer Di.					Observer F.				
Heard out—	Left		Right			Left		Right		
Interval	+	−	+	−	*Q*	+	−	+	−	*Q*
2″.....	11.5	13.5	17.0	8.0	.29	14.0	11.0	14.5	10.5	.28
1″.....	12.0	13.0	14.5	10.5	.12	14.5	10.5	16.0	9.0	.42
4″.....	16.5	8.5	14.0	11.0	.42	14.5	10.5	15.0	10.0	.35
2″ (*b*).....	13.0	12.0	19.0	6.0	.55	15.5	9.5	14.0	11.0	.35
2″.....	14.0	11.0	18.0	7.0	.53	17.5	7.5	11.0	14.0	.29
2″.....	14.0	11.0	15.0	10.0	.31	12.5	12.5	15.5	9.5	.24
2″.....	13.5	11.5	14.0	11.0	.20	18.0	7.0	14.0	11.0	.53
Totals.....	94.5	80.5	111.5	63.5	.34	106.5	68.5	100.0	75.0	.34

(*a*) This table gives the total plus and minus judgments in each part-series of 25, instead of excess judgments as in Tables I. and II. For example, observer Di. had 2 series with an interval of 1 second between the preliminary and record stimuli. Out of 25 cases where he heard-out to the left he made 15.5 left judgments and 9.5 right judgments, in the first series. Under the same circumstances, in the second series, 14.5 were judged to the lef and 10.5 to the right.

(*b*) The stimulus for the first and third of these last four series was weak for each *O*, and for the second and fourth, it was moderately intense. (*Cf.* next page.)

TABLE III

JUDGMENTS CONSEQUENT TO HEARING-OUT ONE COMPONENT OF A BINAURAL TONE

A. Eye-Movement to the Same Side

	Observer H.					Observer S.				
Heard out—	Left		Right			Left		Right		
Interval	+	−	+	−	Q	+	−	+	−	Q
1″	16.5	8.5	15.0	10.0	.49	16.5	8.5	13.0	12.0	.36
1″	11.5	13.5	10.0	15.0	−.28	14.0	11.0	16.5	8.5	.42
4″	18.0	7.0	11.5	13.5	.37	12.5	1 .5	18.5	6.5	.48
4″	15.5	9.5	13.0	12.0	. .8	14.0	11.0	16.0	9.0	.39
2″	14.0	11.0	11.0	14.0	.00	15.0	10.0	17.5	7.5	.56
2″	13.0	12.0	12.5	12.5	.40	14.0	11.0	21.0	4.0	.44
Totals	88.5	61.5	73.0	77.0	.15	86.0	64.0	102.5	47.5	.49

B. Central Visual Fixation

	Observer H.					Observer S.				
Heard out—	Left		Right			Left		Right		
Interval	+	−	+	−	Q	+	−	+	−	Q
2″	15.5	9.5	14.0	11.0	.35	12.5	12.5	16.5	8.5	.32
1″	13.0	12.0	12.5	12.5	.40	14.0	11.0	17.0	8.0	.48
4″	17.5	7.5	9.5	15.5	.18	15.0	10.0	15.0	10.0	.38
2″ (*a*)	14.0	11.0	13.0	12.0	.16	15.0	10.0	17.0	8.0	.52
2″ (*b*)	13.0	12.0	18.0	7.0	.47	17.0	8.0	12.5	12.5	.36
2″	13.0	12.0	17.0	8.0	.39	15.5	9.5	18.5	6.5	.65
2″	9.5	15.5	18.0	7.0	.22	16.0	9.0	13.0	12.0	.32
Totals	95.5	79.5	102.0	73.0	.31	105.0	70.0	109.5	65.5	.40

Comparison of the individual coefficients of Tables III., *A* and III., *B* would seem to show that there is no significant correlation between the M.V. and eye-movement to the side heard-out, for the limited number of cases here presented.

The first two 'intensity series' (*a*) and (*b*) are comparable inasmuch as they were both made on the same day, one following the other. This was true in the case of each *O*. The same was true of the second pair of intensity series. The estimated intensity of the total binaural stimulus used in the first series of both pairs is 0.000 000 152 cm. and in the second series 0.000 004 178 cm.

Six out of the eight comparisons, *i.e.*, two for each *O*, show a higher coefficient for the weaker stimulus. This would seem to show that the attention insofar as the attention-set consequent to hearing-out is concerned, is more effective in the case of the weak than the stronger binaural sound used.

TABLE IV

THE GROUP TOTALS OF RECORD JUDGMENTS FOR GROUP II, AND THE CORRESPONDING COEFFICIENTS OF ASSOCIATION BETWEEN ATTENTION TO ONE SIDE AND JUDGMENTS TO THE SAME SIDE

A. Eye-Movement to the Side of Attention

Observer	Heard out Left		Right		Judg't Totals	*Q*
	+	−	+	−		
Di	85.0	65.0	97.5	52.5	300	.42
F	104.0	46.0	117.0	33.0	300	.78
H	88.5	61.5	73.0	77.0	300	.15
S	86.0	64.0	102.5	47.5	300	.49
Totals	363.5	236.5	390.0	210.0	1200	.48

B. Central Visual Fixation

Observer	Heard out Left		Right		Judg't Totals	*Q*
	+	−	+	−		
Di	94.5	80.5	111.5	63.5	350	.34
F	106.5	68.5	100.0	75.0	350	.34
H	95.5	79.5	102.0	73.0	350	.31
S	105.0	70.0	109.5	65.5	350	.40
Totals	401.5	298.5	423.0	277.0	1400	.34
Sums of Totals	765.0	535.0	813.0	487.0	2600	.41

Inspection of column *Q* reveals several interesting relations. The coefficient of any *O* as found in IV., *A*, is appreciably different from that in IV., *B*. For three of the *O*'s the coefficient in IV., *B*, is considerably less than in IV., *A*, while for the remaining *O* it is greater. It would seem that in cases where we have eye-movement to the side of the attention, there is an increased tendency to judge the phantom as on the same side.

While it is perhaps not legitimate to make inferences from the fact, the group totals show an interesting relation. Whereas in IV., *A*, they are widely different, in IV., *B*, they are within .09 of each other. The M.V.'s are respectively .18 and .03, or as 6 to 1. The decreased deviation may be partially a result of the elimination of individual differences due to eye-movement.

coefficient is greater or less than it would be if a wider or narrower range of relative intensities in the binaural components were used. Consequently our figures have no absolute or exact quantitative value. In a few supplementary experiments, however, it was found that if the binaural phantom as physically conditioned, was at one limit of the particular range of relative intensities which we used, say to the left, it was barely possible to hear-out the right component even though it was physically conditioned by the weaker stimulus. This was roughly true for all the *O*'s tested, and serves to give our figures a little more than mere relative value.

However, the most significant thing about the coefficient of association is that in every series, with two exceptions for observer H., it indicates some degree of shift to the side to which the attention is directed.

IV. CONCLUSION

The important difference in the conditions of our two groups of experiments was, that in Group I. the preliminary stimulus was uniaural and served as an aid to the direction of the attention; whereas in Group II. the preliminary stimulus was binaural and the attention was voluntarily and arbitrarily directed to a given component. We may interpret the results of the groups separately and then state their combined indications.

1. The results of Group I. clearly indicate a biased sensory fatigue-effect resulting from the employment of an uniaural preliminary stimulus (Table I.).

2. As far as its influence on the position of the phantom is concerned this fatigue effect is a very delicate and variable phenomenon.[1] The experiments with different interstimulation intervals suggest a recovery from fatigue, or an increase in intensity of sensation, when the interval between the uniaural and the record stimulus is changed from 1 to 4 seconds.

3. The results of the few experiments on the effect of

[1] These results are in harmony with those of Flugel, J. C., 'On Local Fatigue in the Auditory System,' *British Journal of Psychology*, XI, 1920, 133–4.

different intensities of stimulation indicate much greater fatigue at the weaker intensity.[1]

4. The results of the few experiments with eye-movement to the side of uniaural stimulation were markedly different from the rest which employed central visual fixation; and seem to indicate that eye-movement tends to counteract the uniaural fatigue effect, as far as localization judgments are concerned.

1. In Group II. both the hearing-out and the attention-set which follows it cause a change in the position of the phantom.

2. The attention-set appears to be a variable as regards duration; but several indicators suggest that it persists for some time. For instance, in over half of the tested cases, the empirical center was found to be farther away from the side to which the attention was directed, at the middle than at the beginning of the series. Also, the *O*'s frequently reported that it was more difficult to hear-out the opposite component in the last half of the series. Two *O*'s felt very sure that their judgment was influenced by the preceding hearing-out. One remarked that there seemed to be a 'hangover' which increased the difficulty of hearing-out the opposite side. All *O*'s reported that after hearing-out one side for a time the process becomes easier and the phantom becomes located more or less continuously nearer to the side of the attention (*i.e.*, the empirical center is farther to the other side). One *O* reported that sometimes, well along in a series, the phantom is already at the to be heard-out side at the commencement of the hearing-out periods. The writer had this experience also.

3. The attention-set may be shifted, apparently, contrary to instructions by a relatively small change in the external conditions. From the introspective reports of the *O*'s and his own record sheet, it was clear to the experimenter that after several cases in which the binaural components were so different that the phantom was judged to be on the side opposite to that heard-out, it was more difficult than usual

[1] *Cf.* Bowditch in Verworn, Max, 'Irritability,' 1913, 164.

to hear-out according to instructions in the subsequent preliminary period.

4. The results of the experiments with different intensities of stimulus seem to show that the attention-set has a greater effect on weak than on strong intensities of sound. Observers occasionally reported increase in total intensity after the experimental series had commenced, which would seem to indicate sensory accommodation or adaptation.

5. One of the most striking introspective facts is the experiencing of various rapid 'shifts' and 'spiral' movements of the phantom. Each *O* experienced something of this sort, though comparatively infrequently. From its character and the sequence of the changes, it seems extremely improbable that the cause was instrumental. "When hearing-out the right, . . . the stimulus will appear, at times, to shift from center to left, and then back to right where it remains." "At times the 5 second stimulus (the preliminary binaural stimulus) shifts from center to left and back to center, sometimes only once, sometimes two or three times." "The shift is a clean-cut and amazing phenomenon, distinctly objective; there is a true illusion of motion; it moved clear across the center to the other side." The above are introspections from three different observers. Sometimes, in hearing-out, the phantom is reported as shifting part way over only to 'slip' back again.

Combining our interpretations, we find five conditions which effect the judgment of position of the binaural phantom, when wave-phase and frequency remain constant, *i.e.*, absolute intensity, relative intensity, sensory fatigue, eye-movement, and attention-set.

1. In both groups of experiments stimulation near the absolute threshold of intensity seems to favor the shift of the phantom.

2. With regard to the direction of the attention, the shift is in opposite directions in the respective groups.

3. The effect of eye-movement is similar in both cases, *i.e.*, an increased tendency to judge to the side of the attention.

4. The shifts and spiral effects which were noted much the more frequently in Group II., according to the introspection, would seem to be due to changes in attention.

Especially interesting is the fact that at the weaker intensity of stimulation we found greater shifts of the phantom both as due to sensory fatigue and to attention-set. The results of our experiments confirm the findings of Stumpf,[1] Nic. Lange,[2] G. E. Müller,[3] and others, *i.e.*, that attention has most effect on weak sensations. Sometime ago Bowditch[4] showed that recovery of irritability after weak stimulation is slower than after strong stimulation. If fatigue and inhibition are both dependent on the refractory phase as Verworn maintains, these two apparently opposed phenomena may both be expressions of the same fundamental neural fact.

We are under obligations to Professor Titchener for pointing out that our experiments do not preclude a shift of the binaural phantom due directly to changes in clearness. But whether the changes in our record experiments are due to clearness or not the fact that it is possible to hear-out one side of the binaural stimulus to the exclusion of the other certainly shows that as a consequence of attention, intensity of audible tone may be reduced to zero.

While our experiments, then, cannot be said to settle the question of whether attention increases the intensity of the component to which it is directed or decreases the intensity of the component from which it is abstracted, the evidence indicates a decreased intensity of the component from which the attention is abstracted. We have no introspective evidence that the heard-out component becomes more intense. As far as these experiments go, change in the relative intensities of the two components would appear to be due to an absolute decrement rather than an absolute increment.

In regard to the general problem, we cannot safely reason from one sensory field to another by analogy. What holds for auditory sensation, in regard to change in intensity, may be expected to hold for other mental facts of the same class. But this is a matter of fact to be settled only by experimentation in the various sense fields.

[1] *Op. cit.*
[2] *Op. cit.*
[3] *Op. cit.*
[4] Cited by Verworn, *loc. cit.*

AN IMPROVEMENT IN VOICE KEYS

BY KNIGHT DUNLAP

The Johns Hopkins University

The voice keys I designed earlier for use in the timing of association reactions were simplified and improved from the Römer key, and have always given some trouble in the adjustment of the contact. The difficulty has arisen from the method of leading in the current to the swinging lever. Sufficiently good conduction cannot be obtained through the bearing of the lever, and I therefore employed a fine wire connection directly from the lever to a binding post. Such a wire connection can be made to work, but if the wire becomes bent (as it easily may, and frequently does, through removal of a cloth cover, or by accidental touches), it changes the pressure of the lever against the diaphragm, breaking the circuit permanently or decreasing the sensitivity of the key. With improvements in the chronoscope, the voice key has remained the only weak point of my Association Timing Apparatus.

The final model of the voice key, illustrated in the cut, removes the last difficulty, offering a key in which the contact is operated by gravity alone, and in which the maximum of sensitivity with maximum of reliability is therefore obtained.

The key consists, as in earlier models, of a brass ring (*S-S*) supported by a brass block (*P*) on a base (*B*) of hard rubber or bakelite. Within the ring is supported a diaphragm (*D*) of thin aluminum, carrying at its center a gold contact plate mounted on a mica disc (*F*). The contact-lever (*L*), with its gold-pointed head (*H*), is pivoted in a bearing (*G*) attached to the top of the ring (*S*): thus differing from the early models, in which the lever was pivoted at the bottom. From the top of the lever extends a bent wire (*W*) dipping into a mercury-cup (*C*).

The contact-plate (*F*) on the diaphragm is connected to a binding post (*J*) by means of a thin wire (not shown). The mercury-cup (*C*) is connected with a similar binding post (not shown) through the ring (*S-S*). In this way, the current is

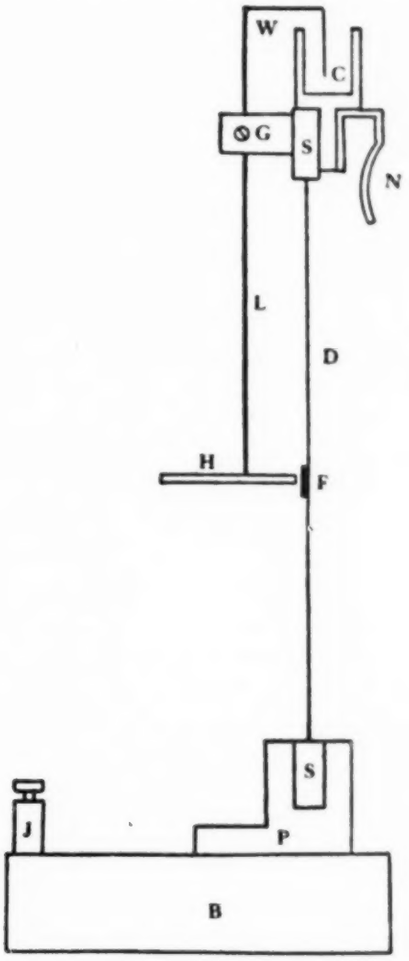


FIG. 1. Cross section of key. *D*, aluminum diaphragm, suspended in ring *B* with supporting block *P*, on base *B*. *L–H*, contact-lever, pivoted at *G*, and with bent extension wire *W* dipping in mercury-cup *C*. *N*, nose-plate. *F*, contact-plate on diaphragm.

led in to the lever, and yet the lever is perfectly free to act under the force of gravity and the vibration of the diaphragm; and by adjusting the inclination of the whole key (by means of a leveling screw in the supporting tripod, not shown), the required pressure of the gold tip of the lever-head against the gold contact-plate can be secured. Since the wire (*W*) does not lift out of the mercury cup (*C*), but merely moves

slightly in the mercury, no trouble is encountered at that point. The key is highly sensitive and satisfactory, and may be considered a final model.

The nose-plate (*N*) attached to the top of the ring (*S*-*S*) is useful in the cases of untrained reactors, who tend often to speak *around* the key, when the experimenter is opposite the reactor. By instructing the reactor to touch the tip of the nose to the plate (*N*) at the command 'ready,' this source of difficulty is easily obviated. With reactors accustomed to the apparatus, the nose-plate is not needed.